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CONTENTS

COLCHICINE-INDUCED TETRAPLOIDS OF SIX VARIETIES OF *VIGNA SINENSIS*[1]

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In *Vigna sinensis* (L.) Savi., three distinct subspecies are recognized: the *sinensis* proper (cowpea), subsp. *catjang* (catjang bean) and the subsp. *sesquipedalis* (asparagus bean, yard long bean). The plants of each group are so conspicuously different from each other that often specific ranks are given to them. Varieties conspicuously different in their habits exist, suitable for cultivation as vegetable, pulse, fodder and green manuring crops.

Tetraploids of several legumes have been obtained by different workers, but so far economic utility has been achieved only in some fodder legumes. Among the seed legumes tetraploidy has been induced in gram (Ramanujam and Joshi, 1941), pigeon pea (Kumar *et al.*, 1945), green gram (Kumar and Abraham, 1942), black gram (Sen and Chedda, 1958), horse gram (Sen and Vidyabhusan, 1958), soybean (Tang and Loo, 1940), pea (Straub, 1940) and bean (Spasojevic, 1956), but reduced fertility has been the main handicap for their economic cultivation. Several fodder legumes have surpassed their diploids in yield. Tetraploid strains of red clover are now being grown by farmers for its high forage value and higher yield (Levan, 1942; Muntzing, 1951). Encouraging results have been obtained with subterranean clover (Hutton and Peak, 1954), and with Egyptian clover (Sikka *et al.*, 1958). Tetraploidy has also been induced in alsike clover (Bragdo, 1955), alfalfa (Cooper, 1938), white sweet clover (Atwood, 1936), Indian clover (Sikka *et al.*, 1958) and in Lespedeza (Hanson, *et al.*, 1959).

In cowpea, which is used both as seed and fodder legume, Capinpin and Reano (1949) successfully used root extract of *Rourea erecta* to induce polyploidy. Sen and Hari (1955) obtained tetraploid cowpea through colchicine treatment of seed. Among the C_2 plants, though the sterility was very high, tetraploid plants expressed gigas features in most of the parts and grew vigorously. The possibility of improving the tetraploids through selection and utilizing them as fodder was indicated. The results of inducing tetraploidy in the three groups of *Vigna* are presented in this paper.

MATERIAL AND METHODS

Six varieties, two from each group of catjang, sinensis and sesquipedalis were selected for inducing tetraploidy.

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[1] Part of the Ph.D. thesis of J. G. Bhowal

Group	*Varieties*
(a) Asparagus bean	(i) Philippine Early, (ii) Globe
(b) Cowpea	(i) Tabara, (ii) Giant
(c) Catjang bean	(i) Barabazar, (ii) Poona

Seed treatment: The concentrations of colchicine solutions and duration of treatments were (a) 0·25 per cent—half an hour, one hour and three hours, (b) 0·1 per cent—one hour, three hours, six hours and 12 hours, (c) 0·025 per cent—three hours, six hours, 12 hours and 24 hours. Prior to treatment, the seeds were soaked in water for eight to 12 hours, the seed-coats quickly removed with forceps, the seeds dried and then dipped in colchicine solution in tubes for half an hour. They were then transferred to petri-dish having a filter paper with the colchicine solution just sufficient to cover half the depth of the seeds, and kept there for the rest of the treatment period, washed in water and allowed to sprout on moist filter paper. The sprouted seeds were sown in wooden boxes containing finely powdered soil mixed with cow-dung manure and the growing seedlings were transplanted in the field plots.

Seedling treatment: The seeds were dibbled two to three in each hole spaced at a distance of 3 ft. × 2 ft. The best seedling in each spot was kept and the apical bud was treated with 0·25 per cent colchicine solution for (i) six hours—one day, (ii) nine hours—one day, (iii) three hours—three days and (iv) six hours—three days; and in 0·5 per cent colchicine solution for (i) six hours—one day, and three hours—three days. The treatments which gave more colchiploids were repeated next year.

For the treatments, a small cotton plug was placed around the bud held between the two leaves, and the colchicine solution was given from a glass dropper. During the treatment, the seedlings were covered with earthenware pots to check evaporation of colchicine solution and more solution was added from time to time to keep the cotton plug moist. Every day after the scheduled period of the treatment the cotton plugs were removed and the apical buds washed with water.

Cytological technique: Meiotic preparations were made following iron-acetocarmine smear technique from flower buds fixed in fresh mixture of acetic-alcohol (1:3). Premordenting in four per cent iron alum for at least half an hour was found essential for good staining. Meiotic studies of the induced tetraploids were made from flower buds of the suspected tetraploid sectors or from tetraploid plants of the C_2 generation. Somatic chromosomes were studied in aceto-orcein squash of root tips pretreated in para-dichlorobenzene for one hour to 1½ hours in 12-14°C. Preparations were made permanent by detaching cover glass in normal butyl alcohol and mounted in balsam. Pollen mother cell spindles were stained in Harri's Haematoxylin in microtome sections made at 20μ thickness following fixation in Nawaschin's fluids A and B (1:1). Photomicrographs were taken at × 250 and reproduced at magnification × 750 and × 1500.

OBSERVATIONS

Effect of seed treatment: As the treated seeds germinated, the root growth was checked and the tip swelled. All parts of seedlings were thicker and smaller and it took

a much longer time to use up the food matter in the cotyledons, which did not shrivel for many days after germination. The percentage of survival in different treatments was 50-80 in 0·025 per cent—three hours, 0-30 in 0·25 per cent—half an hour, and 0-30 in 0·025 per cent—six hour, treatments. No seedlings survived in the other treatments.

The surviving seedlings grew slowly. The first pair of leaves was very small and thick. The hypocotyl and epicotyl remained shorter and thicker. The seedlings, when transplanted in the field, grew slowly and had a stunted appearance. They showed some modifications and malformations of the leaves. Only two tetraploids were obtained through seed treatment, one in the variety Philippine Early and the other in the variety Poona, both in the 0·025 per cent—three hour treatment.

Effect of seedling treatment: After treatment, the growth of the seedlings was practically arrested for about a week. The first few leaves were very small and deformed. These malformations were generally seen in the first three-four leaves, but sometimes even up to the seventh leaf. In most of the treated seedlings, two to three branches were found to grow simultaneously from the tip of the seedlings. In some treated seedlings, a cluster of four or more equally growing branches was found. The first pair of leaves in all the treated seedlings became more green and thick.

In general, the seedlings that developed polyploid sectors were more stunted and slow-growing. As the plants grew, the tetraploid branches could be easily distinguished.

TABLE I. COMPARATIVE EFFECTS OF THE DIFFERENT SEEDLING TREATMENTS ON THE PRODUCTION OF COLCHIPLOID PLANTS

Treatments	Seedlings treated	Colchiploids produced
0·25 per cent —6 hrs. —1 day	30	7
0·25 per cent —9 hrs. —1 day	72	18
0·25 per cent —3 hrs. —3 days	30	5
0·25 per cent —6 hrs. —3 days	72	15
0·5 per cent —6 hrs. —1 day	72	15
0·5 per cent —3 hrs. —3 days	30	8

The comparative effects of tetraploidy were studied with the tetraploid progenies of these mixoploid plants. In general, seeds of the tetraploids took a longer time to germinate. The seedlings were stouter, succulent and slow-growing. The leaves were shorter, but broader in the varieties Tabara, Giant and Barabazar. In Poona and Philippine Early, they were longer as well as broader. In all varieties, the leaves were broader, having a smaller length/breadth ratio (Table II). The most conspicuous features of the leaves were their dark green colour and thickness. Section of the leaf showed that both cells of palisade and spongy parenchyma were bigger.

Stomata were larger, but fewer in number. The stem was thicker and the internodes shorter. The length of the main stem was also less than the diploid and fewer branches were produced.

The tetraploid plants bloomed later; on an average, they took 15-20 days more than the diploids. The flowers and all the floral parts were bigger. The tetraploid plants of all the varieties had a much longer blooming period and they bore many more flowers. Fruit-setting was greatly reduced.

COLCHICINE-INDUCED TETRAPLOIDS OF SIX VARIETIES OF *VIGNA SINENSIS*

1. A DIPLOID AND A TETRAPLOID PLANT OF VAR. TABARA. 2. MITOTIC METAPHASE OF DIPLOID TABARA. 3. MITOTIC METAPHASE OF TETRAPLOID TABARA. 4. MITOTIC METAPHASE OF TETRAPLOID BARABAZAR.

More sterility of the pollen grains was characterisitc of the induced tetraploid plants of all the varieties. In the normal diploid plants pollen sterility seldom exceeded five per cent. In the tetraploid plants of different varieties, pollen sterility varied from about 26 to 90 per cent in 1956 and 16 to 90 per cent in 1957 (Table III)

TABLE II. COMPARATIVE EFFECT OF TETRAPLOIDY ON LEAF AND FLOWER IN DIFFERENT VARIETIES (MEASUREMENT IN CM.)

		Tabara	Giant	Barabazar	Poona	Philippine Early	Globe
1. *Leaf*							
Length	2n	10·5	11·49	11·88	9·70	11·45	..
	4n	10·0	9·63	9·96	10·70	11·90	..
Breadth	2n	8·31	8·73	8·38	6·36	5·80	..
	4n	9·78	8·81	8·43	9·70	7·30	..
Ratio L/B	2n	1·26	1·30	1·41	1·52	1·97	..
	4n	1·02	1·09	1·18	1·07	1·63	..
2. *Flower*							
Length	2n	3·95	2·92	2·50	2·65	2·89	2·99
	4n	3·24	3·16	2·93	2·92	3·09	3·14
Breadth	2n	3·37	3·26	2·73	2·84	3·10	3·24
	4n	3·92	3·86	3·25	3·20	3·65	3·86

In some of the tetraploid flowers of Poona and Giant, the anthers did not burst at all, while in others where anthers dehisced discharge of pollen grains was very meagre. Sterility of the pollen grain in these undehisced anthers was very high.

Fruit-setting in the tetraploids, except in the variety Tabara, was very low (Table III). The varieties Giant and Poona with high pollen sterility failed to produce any fruit.

TABLE III. PERCENTAGE OF POLLEN STERILITY AND THE NUMBER OF FRUITS PER PLANT IN TETRAPLOIDS

Variety	Per cent pollen sterility		Fruits per plant	
	1956	1957	1956	1957
Tabara	29·80	37·36	14·18	2·5
Giant	62·43	81·90	Nil	Nil
Philippine Early	29·00	29·00	0·66	0·33
Globe	..	36·36	..	0·16
Barabazar	26·00	16·52	0·12	0·22
Poona	90·00	90·00	Nil	Nil

Fruits of the tetraploid varieties were always smaller than those of the respective diploids, and had fewer seeds. In the few fruits that were collected from the tetraploid plants of Philippine Early and Barabazar, the number of mature seeds per fruit generally was one to three, rarely four. In Tabara, where the fertility was the highest, the number of mature seeds varied from one to six. Though the fruits of the tertraploid plants were small and the number of mature seeds obtained were few, the number of ovules formed in the ovary was more or less like the diploids. However, the seeds of all the tetraploid varieties were bigger in size (Table IV).

TABLE IV. COMPARISON OF FRUIT LENGTH (IN CM.) SEED SETTING AND SEED WEIGHT (IN GM.) IN DIPLOIDS AND TETRAPLOIDS

	Tabara		Philippine Early		Barabazar	
	2n	4n	2n	4n	2n	4n
Fruit length	19·38	9·53	26·45	7·43	9·65	9·50
Number of seeds per fruit	16·66	3·20	18·9	1·66	13·29	2·00
Weight 10 seeds	1·83	2·20	1·2	1·72	0·50	0·70

The seeds of the tetraploid plants of all the varieties were generally found to be larger in size. But a few tetraploid seeds in all varieties were like those of the diploids, sometimes even smaller. Some of the seeds were also shrunken.

Cytology: In all the diploid varieties, meiosis was normal showing eleven bivalents at diakinesis and the first metaphase. At anaphase, disjunction of the bivalents was regular. In the first and second anaphases, eleven chromosomes per pole were observed. Lagging chromosomes, unequal separation or other meiotic irregularities were not observed. Some meiotic irregularities were, however, observed in the variety Poona, where grouping of bivalents was observed in polar view of several metaphase I plates, though very few cells showed more than two spindles in the anaphase II and consequent separation of chromosomes in more than four poles.

In the tetraploids, bivalents were most common, though quadrivalents, trivalents and univalents were present in most of the cells. Frequency of the different types of chromosome configurations is given in Table V. This frequency was counted from twenty diakinesis or/and metaphase plates. Higher valency was very rarely observed. One cell with a hexavalent was observed in the first metaphase of the variety Giant. In all the varieties, 22 chromosomes in each pole were observed in the first anaphase. Cases of nondisjunction were occasionally observed only in the variety Giant. Lagging of one or two bivalents in the interpolar region of the spindle was not rare.

Unequal distribution of chromosomes in the first anaphase was a common feature. Early separation of chromosomes and the consequent precocious movement were also noticed. Frequency of lagging and unequal distribution were calculated from a large number of cells (Table VI). In the variety Poona, the first anaphase was highly

irregular with frequent occurrence of multipolar (generally tripolar and quadripolar) separation of chromosomes. The percentage of multipolar separation was 26·03.

TABLE V. FREQUENCY OF DIFFERENT CHROMOSOME CONFIGURATIONS IN MEIOSIS

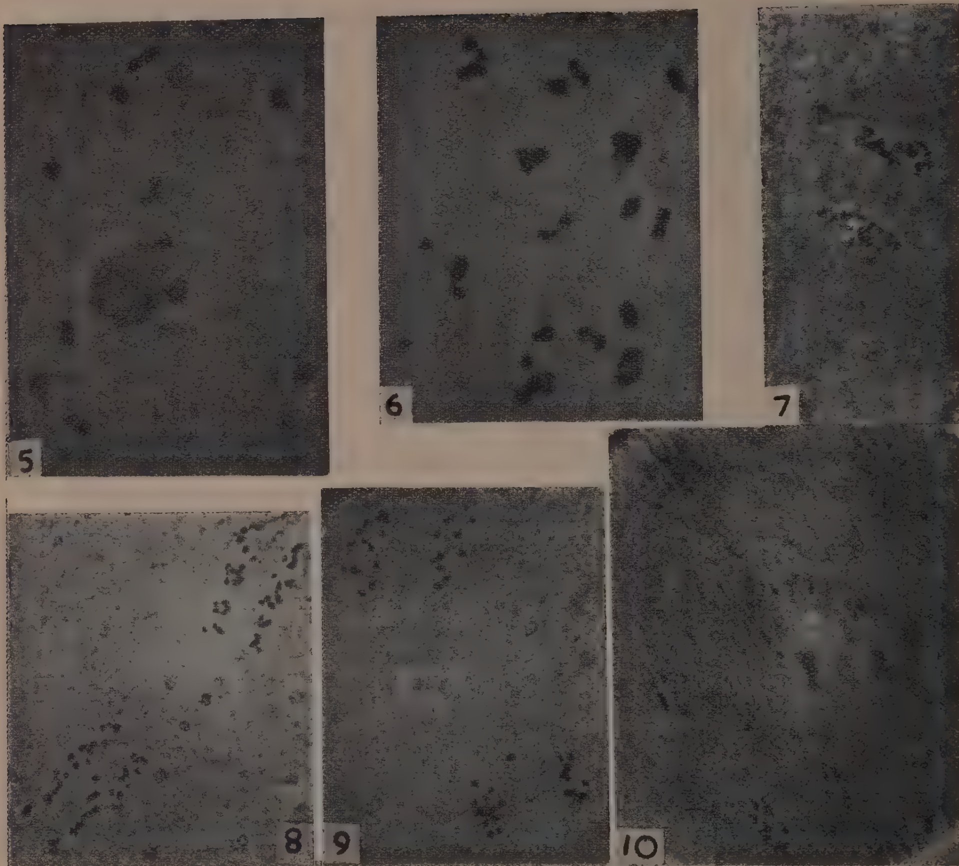
Varieties	IV-valent		III-valent		II-valent		I-valent	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Tabara	1–5	2·8	0–2	0·35	10–20	15·60	0–2	0·55
Giant	1–8	3·4	0–3	0·35	6–16	11·30	0–3	0·65
Philippine Early	0–7	2·45	0–2	0·65	4–22	15·65	0–3	1·55
Globe	1–4	2·10	0–3	0·95	12–20	16·0	0–7	1·10
Barabazar	0–5	2·25	Not found		12–22	17·50	Not found	
Poona	0–6	2·4	0–3	0–90	8–22	15·0	0–4	1·50

TABLE VI. MEIOTIC IRREGULARITIES AND POLLEN STERILITY

Varieties	Anaphase I per cent unequal separation	Interphase per cent laggards	Anaphase II per cent unequal separation	Per cent polyspored cells	Per cent pollen sterility
Tabara	16·20	3·03	21·42	13·09	29·80
Giant	*	*	*	Nil	62·43
Philippine Early	5·88	8·69	28·57	8·90	29·00
Globe	25·00	7·89	*	20·69	36·36
Barabazar	16·66	Nil	*	15·05	26·00
Poona	4·10	4·10	*	54·49	90·00

*Only few good cells could be studied.

The only abnormality generally observed in the second division was unequal separation of chromosomes in the anaphase II. The irregularities in the second anaphase in tetraploid plants of Poona were very conspicuous. The most characteristic feature was the frequent occurrence of multipolar cells. The chromosomes were found to be grouped in more than four poles by the formation of three or more spindles. Some chromosomes could not arrange themselves in any group and were found to be scattered irregularly in the cells. The resultant feature was the second telophase cells with many nuclei and the ultimate formation of pentads, hexads, heptads, octads, etc., in high percentage. Polyspored cells have been observed also in other varieties, except the variety Giant, even though the numerous cells were examined. Polyspored



5. Diakinesis of diploid Philippine Early. 6. Metaphase I of tetraploid Tabara. 7. Anaphase I of tetraploid Tabara, showing two laggards. 8. Anaphase II of tetraploid Giant. 9. Anaphase II of diploid Giant. 10. Anaphase II of tetraploid Poona, showing multipolar grouping of chromosomes.

cells in other varieties were few and the extra spores were very small. In Poona, all the spores in a cell were more or less of the same size.

Mitosis: The somatic chromosome number in the tetraploid varieties was studied from the root tip cells from seeds of the C_1 plants in Tabara and Barabazar. Forty-four chromosomes were observed in both the varieties.

DISCUSSION

The experiments to induce tetraploidy in different varieties of cowpea, catjang bean and asparagus bean by colchicine treatment have shown that treating the apical bud of the seedling with colchicine solution is a very suitable method. Practically

all the doses have given one or more polyploids in the two colchicine concentrations 0·25 and 0·5 per cent used. Treatments with 0·5 per cent for six hours have given the maximum number of tetraploids. On the contrary, treating the seeds in various concentrations of colchicine solution (0·025, 0·1 and 0·25 per cent) and different durations (half an hour to 24 hours) has given very few tetraploids.

Comparative effectiveness of seedling treatment over seed treatment in inducing polyploidy with colchicine in leguminous plants has been reported by many workers. Evans (1955) compared the effectiveness of different techniques commonly used and found that the seedling treatment gave best results in *Trifolium pratense L.* Armstrong and Robertson (1956) reported that tetraploids of *Trifolium hybridum L.* were easily produced by immersing the top of seedlings in 0·2 per cent aqueous solution of colchicine for 12 hours. In *Phaseolus radiatus*, Kumar and Abraham (1942) obtained tetraploids following seedling treatment, where seed treatment completely failed.

Examples of the effectiveness of seed treatment in legumes are not also rare. In *Trifolium pratense* L., Bragdo (1955) got higher percentage of total tetraploids by seed treatment than by seedling treatment. Ramanujam and Joshi (1941) successfully produced several tetraploids of *Cicer arietinum* L. by seed treatment.

In *Vigna sinensis*, the main reason for the failure of the seed treatment seems to be the checked root growth of the affected plants, which could not be overcome even with the best cultural conditions provided.

Most of the affected plants following seedling treatment have been found to be chimaeras of diploid and tetraploid sectors. The chimaeral nature of the colchicine treated plants is expected and has been reported by several workers.

Giganticism in several morphological characters has been found to be associated with tetraploidy. In general, tetraploid plants are shorter in height having a stouter stem with short internodes. They are less spreading and have fewer branches. Leaves are shorter but broader in three varieties, and longer as well as broader in two varieties. The length and breadth ratio is, however, smaller than the diploids in all the varieties. They are thicker and darker-green in colour. Both spongy parenchyma and palisade cells are larger in size. Stomata are larger but fewer per unit area. The flowers are conspicuously longer and broader. Pollens are larger and variable in size. Tetraploid plants bear more flowers but set fewer fruits, which are smaller in size and with less number of seeds. The seeds are, however, larger but more variable in size.

Giganticism in many characters is a common feature and is generally associated with the primary effect of tetraploidy in increasing cell size or volume. Increased cell size has been observed in all parts of tetraploid plants of the varieties of cowpea, catjang bean and asparagus bean. A decrease in leaf length and fruit size seems to be associated with larger cells, but reduction in their number.

The tetraploid plants grow slowly and flower later than the diploids. They have a much longer flowering period, and in general the growth period is prolonged. The slower rate of growth in tetraploids has been attributed to the reduced rate of cell division (Kostoff, 1940), smaller amount of growth hormone present (Avery and Pottorf, 1945) and slower rate of metabolic activities in tetraploids. Schwanitz (1950) suggested that the slower growth and delayed flowering of tetraploids are due to

dulled permeability, respiration and transpiration impeding the transfer of food from the sites of manufacture to the places of utilization.

The common meiotic irregularities associated with multivalent formation in the autotetraploids have been observed in the induced tetraploids. The number of quadrivalents in diakinesis and the metaphase I is low, with an average of two to three per cell in different varieties. Trivalent and univalent formations are still less frequent. Lagging chromosomes and unequal distribution of chromosomes at anaphases are seen. The varieties differ from one another in the frequency of quadrivalent, trivalent, univalent and other meiotic irregularities. In the variety Poona, the anaphase I has been found to be highly irregular with frequent occurrence (about 26·03 per cent) of tri- or quadri-polar groupings of chromosomes. More than two spindles have often been seen in the anaphase II. This results in the grouping of chromosomes in more than four poles with a few scattered chromosomes. Each of these clusters ultimately gives rise to spores of variable sizes. More than half of the pollen mother cells have five or more of these spores, the maximum number observed being ten. More than four spores have also been observed in other varieties, but the frequency is low and the extra spore is very small (microspore).

Formation of tripolar and quadripolar spindles has been reported in some animals. Recently, some aberrant types of spindles—broad, elongate, curved, branched, tripolar and triangular, have been observed in the metaphase I of *Bromus* hybrids by Walters (1958). In the second division, she observed two to six independent spindles. Darlington and Thomas (1937) observed in a Festuca-Lolium hybrid derivative that the metaphase I spindle had diffused poles or sometimes a number of parallel but separate spindles. These "incompact" spindles resulted in divergence of groupings of chromosomes to form three or four telophase I nuclei. Clark (1940) observed non-convergence of spindle fibres in Zea at the anaphase I, resulting in multinucleate microsporocyte in the telophase I; at the metaphase II, individual microsporocytes usually contained several spindle figures oriented in various ways. In this investigation, spindle in the metaphase I side view has been found to be normal bipolar with converging fibres. The aberrant spindles such as branched, tripolar or triangular, etc., have not been observed. But three, four or more spindles have been observed in the metaphase II. It seems that tri- or quadri-polar grouping of the chromosomes in the anaphase I is due to weak spindle mechanism. Each of the groups thus formed has the spindle-organising capacity and forms a spindle during the second meiotic division, resulting in a multipolar grouping of the chromosomes. Formation of three independent spindles in the anaphase II has been observed also in the diploid of the variety Poona, though not frequently. Moreover, in a polar view of the metaphase I, bivalents have been found to arrange in different irregular groups. The weakness of the spindle mechanism in the diploid level is made conspicuous at the tetraploid level, making frequent tri-polar and quadri-polar groupings.

Considerable varietal difference in seed-setting has been seen among the tetraploids. The two varieties with very high pollen sterility are completely sterile and do not set any seed. The varieties with comparatively less sterile pollen produce some seeds, in the variety Tabara fruit- and seed-setting are moderately good.

The low fertility of autotetraploids has been attributed to cytological abnormalities such as misdisjunction of multivalents, unpaired chromosomes at anaphase, lagging chromosomes at anaphases, spindle abnormalities, etc. All these cytological abnormalities and the consequent pollen sterility can partly account for the seed sterility of the tetraploid varieties of cowpea, catjang bean and asparagus bean. That some other factors are affecting it, is evident. Some embryological abnormalities also may operate. It has been found that in some cases fruits started to grow with seeds, which ceased to grow after some time and dried away prematurely. Post-fertilization abnormalities causing seed abortion have been observed by Hakansson and Ellerstrom (1950) in rye. Post-fertilization abnormalities producing an abnormal embryo and endosperm may be the cause of such fruit dropping. Prefertilization abnormalities or haplontic sterility seem to play a role in the high sterility of the variety Giant where the few stainable pollens may not be functional and all the flowers drop like unpollinated ones.

Probabilities of gene-conditioned reduced fertility have been suggested by Randolph (1941) in maize. Stebbins (1947) is of opinion that sterility is mainly due to genetically controlled factors of an unknown nature. Kuckuck and Levan (1951) attributed it to the upsetting of the delicately balanced system of genic interaction consequent upon chromosome doubling. Parthasarathy and Rajan (1953) suggested that like many other economic characters fertility is also governed by a system of polygenes or modifier genes which is in a balanced state in the diploid. They further suggest that the disturbed balance can be restored at the tetraploid level by the adoption of suitable breeding procedures.

Differential response of the varieties to tetraploidy in morphological characters, meiotic irregularities and to fertility is seen among the six varieties studied here. Among the six tetraploids varieties only one has shown some promise. Such differential response at the tetraploid level has been observed in many crop plants. Works of Kuckuck and Levan (1951) in linseed types, and Muntzing (1943) in barley, etc., show that varieties or strains within a species differ in their response to tetraploidy. The results of tetraploid breeding indicate that only in rare cases are the primary polyploids, the so-called raw-polyploids, practically useful. In most cases, it is necessary to improve this material by recombination and selection, and by such work vigour as well as fertility may be improved; Kuckuck and Levan (1951) have been able to improve tetraploid linseed up to 80 per cent of diploid by selection alone.

SUMMARY

Tetraploids of six varieties, two from each of cowpea, catjang bean and asparagus bean, have been produced by colchicine treatment.

Treating seeds in colchicine solutions for different durations has given very few tetraploids. Treating the apical buds of the seedling, however, has produced one or more tetraploids in all the treatments. The treatment in 0·5 per cent colchicine for six hours has given the maximum number of tetraploids in all the varieties.

Most of the affected plants were chimaeras of diploid and tetraploid sectors.

The tetraploid plants have stouter stems, broader, thicker and darker green leaves, larger but fewer stomata and larger flowers. They bear more flowers, but set few fruits which are smaller in size with less number of seeds. Seeds are, however, larger.

The tetraploids grow slowly, bloom later than diploids and have a longer growth period.

Marked varietal differences have been observed in the morphological characters, pollen sterility, fruit-setting and in meiotic irregularities.

The common meiotic peculiarities in the autotetraploids like formation of quadrivalents, trivalents and univalents and the occurrence of laggards and an unequal distribution in the anaphases, have been observed. The frequency of quadrivalents in a cell is comparatively low, the average number being two or three per cell.

Pronounced meiotic abnormalities have been observed in the tetraploids of the variety Poona with frequent tri- or quadri-polar separation of chromosomes in the anaphase I, resulting in more than two spindles in the anaphase II and ultimate formation of high percentage of polyspored cells.

Sterility of most of the tetraploid varieties seems to be a limiting factor in their economic utilization. One of the varieties has, however, shown comparatively good fertility. Having a good vegetative growth, it has the potentiality of being used as fodder.

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A PERITHECIA-FORMING ISOLATE OF *COLLETOTRICHUM* SPECIES FROM SUGARCANE

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In course of studies on the red rot disease of sugarcane in West Bengal, the authors came across a case of infection on the Co. 527 variety of sugarcane growing in the field. On the midrib regions of the fully grown living leaves, small reddish spots, bearing a few immature perithecia, were noticed. Small bits of infected lesions were placed, after proper surface sterilization, both on sterile glass slides in moist chamber and in potato-dextrose agar slants. In both the cases, mycelia appeared that produced conidia in acervuli, typical of *Colletotrichum* sp. and later perithecia. As the isolate showed ready and spontaneous formation of perithecia in culture, it was considered fruitful to carry out detailed investigations with the isolate and the results obtained are presented below.

OBSERVATIONS

Morphology of the isolate: The isolate was first purified by taking monoascosporus culture and then grown in petri-dishes containing potato-dextrose agar medium. The morphology of the isolate is as follows:

The fungus shows copious, fluffy growth of dark grey mycelia. Conidia are present in dark grey acervuli which are scattered irregularly over the medium. Conidial stage lasts for six to eight days, and then disappears when perithecia are formed. This sequence of appearance is noticed in each generation. Conidia are borne on conidiophores which are hyaline and short with pointed ends. Setae also are present. They are dark brown, stiff and long with pointed tips, and possess light brown cylindrical or bulbous base. They measure 105-210 $\mu \times 3{\cdot}6$-$4{\cdot}5\ \mu$. Conidia are one-celled, hyaline and fusoid with acute ends, measuring 14-18 $\mu \times 3{\cdot}4$-$5{\cdot}2\ \mu$ with an average of $16{\cdot}0\mu \times 4{\cdot}4\mu$. Perithecia appear within ten to 12 days of growth, mostly occupying the position of acervuli. They are in groups, forming black stromatic masses. Perithecia are dark brown in colour, nearly globular in shape with ostiole slightly protruding. They measure 105-300 μ (average 192 μ). Asci are numerous, closely packed within the perithecia and are interspersed with profuse paraphyses. Each ascus is hyaline and clavate in shape with well-marked basal region. Asci measure 32-72$\mu \times 6$-12 μ, averaging $52{\cdot}8\ \mu \times 9{\cdot}0\ \mu$. Ascospores are eight in number and arranged in biseriate rows within each ascus. Each ascospore is single-celled, hyaline when young, turning light brown with age. Ascospores are elliptical to slightly curved with obtuse ends, and contain several vacuoles within. Ascospores measure 16 to 28 $\mu \times 4$ to 8 μ(average $19{\cdot}4\ \mu \times 5{\cdot}6\ \mu$).

Cultural studies: All cultural studies were carried out in petri-dishes measuring ten centimetres in diameter, containing 20 c.c. of the medium in each case. The

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petri-dishes were inoculated at the centre with mycelial bits of seven days old culture maintained on P.D.A. slants incubated at 20° C, and were maintained at a temperature of 25°-27° C. The colony diameter of the culture was measured along two directions at right angles to each other. The average mean radial growth was then noted in terms of millimetres. Cultural characters were observed on a large number of media, viz., potato-dextrose agar, oatmeal agar, Czapek dox agar, cane-leaf decoction agar (Abbott, 1938) and cane-juice agar; and in each case a replicate of three was used. The average mean radial growth and the growth characters of the fungus are presented in Table I.

TABLE I. LINEAR RADIAL GROWTH AND GROWTH CHARACTERS OF *COLLETOTRICHUM* SP. IN DIFFERENT MEDIA

Medium	Radius of the colony (mm.)	Growth characters
Potato-dextrose agar	35·5	Copious growth with fluffy mycelia. Colour changes from ash-white through ash-grey to dark grey with the advancement of age. Perithecial stroma often aggregate into groups.
Oatmeal agar	33·5	-as above-
Czapek dox agar	31·0	Mycelia blackish in colour. Distinct zonation present. Perithecial stroma mostly solitary.
Cane-leaf decoction agar	42·0	Luxuriant vegetative growth. Mycelia light yellow in colour. Perithecial stroma are relatively few in number.
Cane-juice agar	39·0	Luxuriant growth with ash-grey velvety mycelia. Perithecial stroma numerous.

According to Abbott (1938), Ramkrishnan (1941) and Chona and Hingorani (1950) most luxuriant vegetative growth and fructification of the genus *Colletotrichum* are obtained on the oatmeal agar medium. But in the present studies it has been observed that cane-leaf decoction agar is best suited for luxuriant growth of the fungus. Saltations appeared as narrow, triangular sectors in all the media with the apex pointing towards the centre and the base towards the periphery of the petri-dish. Sectors remained distinct from the parent culture with their light or dark coloured mycelia, as the case may be. Moreover, conidial acervuli and perithecia were relatively less in the saltant than in the parent.

Pathogenicity tests: A series of inoculations were performed with the fungus on sugarcanes, both young (one week old) and adult (six months old). The canes were inoculated by making an incision on the young shoot and placing the inoculum therein and then covering it with moist absorbent cotton. The adult canes were inoculated by the 'plug' method (Chona, 1954). It was observed after two months that the plants were very susceptible at the younger age. Such plants hardly produced three to four leaves and started drying up from the top. Drying up followed downwards till the entire plant withered totally. When the lower leaves and leaf-sheaths of an affected plant were stripped off, the main slender stalk was observed to bear numerous

perithecia on the surface. In some cases, acervuli with conidia were also noted. The identity of the fungus was confirmed by reisolation test. In the adult canes, the fungus failed to spread within the stalk to any significant length. Older leaves also remained unaffected.

Further work to identify the species and also to determine its exact role with regard to sugarcane infection is in progress.

SUMMARY

A species of *Colletotrichum*, isolated from infected sugarcane leaves, showed spontaneous production of perithecia in culture in 10-12 days, after a brief and transient conidial stage.

The isolate showed luxuriant growth of dark-coloured mycelia in a number of media, including cane-leaf decoction agar and cane-juice agar. Perithecia were also produced in all the media tried.

Pathogenicity tests with the fungus showed the plant to be very susceptible at the young age.

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PRELIMINARY STUDIES ON THE EFFECT OF CULTURAL FACTORS AND NITROGEN FERTILIZERS ON GROWTH AND YIELD OF SPRING (*BORO*) PADDY

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Detailed studies have been made on the effects of cultural factors such as the time of transplanting, age of seedlings, spacing, number of seedlings per hole by Chakravorty *et al.* (1936), Hedayetullah *et al.* (1944, 1947), and on nitrogen fertilizers in both laterite and alluvial soils under the auspices of the Rice Research Scheme, Bengal (1939-44) on the growth and yield of *aman* paddy, but practically nothing is known about the cultural and manurial requirements of *boro* paddy. This paper gives an account of the preliminary studies on this aspect.

MATERIAL AND METHODS

Cultural: This experiment was conducted during 1952-53 with the Kakuria variety of *boro* paddy with six dates of planting at an interval of 15 days beginning December 1, 1952 and ending February 14, 1953, with three spacings—four, six and nine inches, and three to four seedlings per hole. The experiment was laid out in split plot design with six replications, the area of each unit plot being 1/131·7 acre. Seedlings, 45-day old, were transplanted in each treatment. Grain and straw yield data were recorded after drying them thoroughly in the sun.

Manurial: This experiment was continued for three consecutive years—1955-56 to 1957-58, with three treatments (control, organic and inorganic manures) on growth and yield of *boro* paddy (the variety Chinsurah *boro*-I had no replications). The organic manure (mustard cake) and the inorganic manure (ammonium sulphate) were applied at the time of final puddling to supply 80 lb. nitrogen per acre. One seedling per hole was transplanted nine inches apart all round, the net area of each unit plot being 1/10·3 acre. Data on plant height, number of fertile and total tillers, length of earheads, length and breadth of the flag leaves and ear emergence, when more than 50 per cent plants had flowered, were recorded from 25 plants selected at random from the plot of each treatment. Grain and straw yield data were collected after drying the seed and straw thoroughly in the sun.

RESULTS AND DISCUSSION

The mean yield of grain and straw in maunds (1 md. =82·29 lb.) per acre under different dates of planting and spacings is given in Table I and their analyses of variance shown in Table II. From the analysis of both grain and straw yield, it is seen that the spacing is significant at one per cent level for grain and five per cent level for straw, while the interaction between the dates of planting and spacings is significant at one per cent level for grain yield only. The date of planting is not significant in both the cases.

Although the date of planting is not statistically significant, it appears from the result that the best time for planting for grain yield is from the end of December to the middle of January as the yield deteriorates progressively with delay in planting. Alim and Sen (1954) have also reported that the best planting time is from late December to mid-January; after that there is a fall in the yield.

The third date of planting (December 31) gives the highest grain yield with a four-inch spacing, which is significantly superior to six inches on five per cent level and to nine inches even on one per cent level. The next best is the fourth date of planting (January 15) with a four-inch spacing and is also significant when compared with six and nine inches. For straw yield, the fourth date of planting gives the maximum yield with a four-inch spacing and then decreases very much with delayed planting. Further studies are in progress to confirm the above conclusion.

Regarding the effect of fertilizers on the growth and yield, it has been observed that the grain yield has increased after the application of ammonium sulphate and mustard cake to an extent of 7·4 maunds and 10·2 maunds per acre, respectively, (average of three years' results) over the control along with an appreciable increase of plant height and length and breadth of the flag; but no marked difference in tillers, ear emergence and length of earheads has been observed between treatments.

TABLE I. (i) DATES OF PLANTING × SPACINGS (MEAN YIELD OF GRAIN IN MAUNDS PER ACRE)

Spacings	Dates of planting						Mean
	1–12–52 I	16–12–52 II	31–12–52 III	15–1–53 IV	30–1–53 V	14–2–53 VI	
4 inches	4·27	4·80	8·53	8·00	5·85	5·32	6·13
6 ,,	4·80	6·65	6·12	5·50	5·72	2·40	5·20
9 ,,	1·26	5·32	4·95	4·65	3·60	2·08	3·64
Mean	3·44	5·59	6·53	6·05	5·06	3·27	4·99

C.D. for spacing at 5 per cent level=0·92
C.D. for spacing at 1 per cent level=1·22
C.D. for interaction at 5 per cent level=2·28
C.D. for interaction at 1 per cent level=3·03

(ii) DATES OF PLANTING × SPACINGS (MEAN YIELD OF STRAW IN MAUNDS PER ACRE)

Spacings	Dates of planting						Mean
	1–12–52 I	16–12–52 II	31–12–52 III	15–1–53 IV	30–1–53 V	14–2–53 VI	
4 inches	42·65	47·72	54·92	58·40	48·00	43·45	49·19
6 ,,	45·72	45·32	35·72	49·60	46·92	42·65	44·32
9 ,,	22·65	42·12	39·20	40·52	35·45	50·12	38·34
Mean	37·01	45·05	43·28	49·51	43·46	45·41	43·95

C.D. for spacing at 5 per cent level=7·22
C.D. for spacing at 1 per cent level=9·60

TABLE II. ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Variance (Md./Acre)		Ratio	
		Grain	Straw	Grain	Straw
Blocks	5	12·70	645·22	0·89	2·71*
Date of transplanting (D)	5	5·20	333·46	0·36	1·40
Error (1)	25	14·21	238·03	..	..
Spacings (S)	2	56·73	1,058·66	14·58**	4·51*
Interaction (S×D)	10	21·84	266·24	5·61**	1·13
Error (2)	60	3·89	234·70	..	..

*Significant at 5 per cent level
**Significant at 1 per cent level

Regarding straw, the highest yield is obtained in ammonium sulphate, next being in mustard cake (Tables III and IV).

Alim and Sen (1954) have found no response on grain yield in spring paddy with the application of organic manures like water hyacinth (raw and rotten), cow-dung, mustard cake and bonemeal, while with the application of ammonium sulphate at the rate of 100 lb., 200 lb. and 300 lb. an increase of grain over the control is noticed, the maximum increase being in 100 lb. ammonium sulphate. Basak *et al.* (1956, 1957) have reported that organic manure as compost and ammonium sulphate when applied singly and in combination at the rate of 30 lb. nitrogen per acre gave a significant increase of grain and straw yield of *aman* paddy over no-manure, slightly higher grain yield being noticed in compost than in ammonium sulphate. In the present study, effects of both organic and inorganic manures have been observed on growth and yield, though the response is more with the application of ammonium sulphate in the first year, while the next two years' results show the highest grain yield in mustard cake. The less response of mustard cake in the first year is perhaps due to the fact that the organic manure did not decompose sufficiently to be of value to the plants as the time taken by the plants from transplanting to flowering is comparatively much less in the first year for delayed transplanting than the time taken by the plants in the second and third years; the poor response to ammonium sulphate in other years is or may be due to the fact that it was applied too early in the season to be available to the plants for their proper growth and yield.

An average of three years' results shows the highest grain yield in mustard cake, ammonium sulphate coming next, while the maximum plant height and length and breadth of the flag are recorded in ammonium sulphate. The difference in tiller numbers, length of earheads and ear emergence between treatments is not so marked. The data taken at the Central Rice Research Institute, Cuttack, and at Nagina, Uttar Pradesh, for plant height, number of leaves, number of tillers, fresh and dry weights of plants, were found higher for manured plots (Sethi, 1952). Further studies with proper number of replications are in progress.

TABLE III. PLANT HEIGHT, NUMBER OF TOTAL AND FERTILE TILLERS, EAR LENGTH, FLOWERING DATES WITH DAYS REQUIRED TO FLOWER FROM SOWING AND GRAIN AND STRAW YIELD (AVERAGE OF 25 PLANTS)

1955-56

Date of sowing—5-12-55
Date of transplanting—11-2-56 to 13-2-56

	Height (cm.)	Total No. of tillers	No. of fertile tillers	Ear length (cm.)	Flowering dates with days required to flower from sowing	Grain yield in md. per plot	Grain yield in md. per acre
Control	$91\cdot6\pm1\cdot08$	$17\cdot6\pm0\cdot39$	$15\cdot8\pm0\cdot27$	$19\cdot8\pm0\cdot21$	12-4-56 (129 days)	2·2	22·7
Mustard cake	$92\cdot7\pm0\cdot92$	$18\cdot5\pm0\cdot64$	$16\cdot7\pm0\cdot61$	$18\cdot9\pm0\cdot44$	9-4-56 (126 days)	2·9	29·9
Ammonium sulphate	$99\cdot1\pm2\cdot05$	$19\cdot2\pm0\cdot63$	$18\cdot3\pm0\cdot68$	$20\cdot1\pm0\cdot18$	13-4-56 (130 days)	3·2	33·0

1956-57

Date of sowing—21-11-56
Date of transplanting—16-1-57 to 18-1-57

	Height (cm.)	Total No. of tillers	No. of fertile tillers	Ear length (cm.)	Flowering dates with days required to flower from sowing	Grain yield in md. per plot	Straw yield in md. per plot	Grain yield in md. per acre	Straw yield in md. per acre
Control	$85\cdot0\pm1\cdot65$	$19\cdot7\pm0\cdot48$	$17\cdot0\pm0\cdot38$	$18\cdot1\pm0\cdot42$	9-4-57 (139 days)	1·8	2·2	18·5	22·7
Mustard cake	$99\cdot4\pm2\cdot16$	$21\cdot2\pm0\cdot55$	$18\cdot8\pm0\cdot48$	$19\cdot4\pm0\cdot33$	8-4-57 (138 days)	3·2	4·0	33·0	41·2
Ammonium sulphate	$98\cdot3\pm1\cdot43$	$21\cdot8\pm0\cdot42$	$19\cdot2\pm0\cdot96$	$19\cdot0\pm0\cdot41$	7-4-57 (137 days)	2·3	3·8	23·7	39·1

1957-58

Date of sowing—12-11-57
Date of transplanting—28-12-57 and 29-12-57

	Height (cm.)	Total No. of tillers	No. of fertile tillers	Ear length (cm.)	Flowering dates with days required to flower from sowing	Grain yield in md. per plot	Straw yield in md. per plot	Grain yield in md. per acre	Straw yield in md. per acre
Control	$81\cdot1\pm1\cdot01$	$16\cdot0\pm0\cdot55$	$13\cdot0\pm0\cdot45$	$18\cdot7\pm0\cdot29$	27-3-58 (135 days)	1·9	3·4	19·6	34·8
Mustard cake	$90\cdot6\pm1\cdot96$	$16\cdot9\pm0\cdot55$	$13\cdot3\pm0\cdot39$	$17\cdot2\pm0\cdot35$	26-3-58 (134 days)	2·8	4·5	28·8	45·8
Ammonium sulphate	$97\cdot6\pm1\cdot07$	$19\cdot5\pm0\cdot50$	$15\cdot8\pm0\cdot47$	$19\cdot1\pm0\cdot28$	25-3-58 (133 days)	2·5	4·9	25·8	50·3

TABLE IV. LENGTH AND BREADTH OF THE FLAG LEAF (AVERAGE OF 25 PLANTS)

	1956-57		1957-58		Average (2 years)	
	Length (cm.)	Breadth (cm.)	Length (cm.)	Breadth (cm.)	Length (cm.)	Breadth (cm.)
Control	$23 \cdot 72 \pm 0 \cdot 78$	$0 \cdot 71 \pm 0 \cdot 03$	$22 \cdot 26 \pm 0 \cdot 59$	$0 \cdot 94 \pm 0 \cdot 01$	$22 \cdot 99 \pm 0 \cdot 49$	$0 \cdot 83 \pm 0 \cdot 02$
Mustard cake	$26 \cdot 26 \pm 0 \cdot 98$	$0 \cdot 87 \pm 0 \cdot 02$	$21 \cdot 83 \pm 0 \cdot 70$	$0 \cdot 95 \pm 0 \cdot 01$	$24 \cdot 05 \pm 0 \cdot 67$	$0 \cdot 91 \pm 0 \cdot 01$
Ammonium sulphate	$27 \cdot 84 \pm 0 \cdot 66$	$0 \cdot 90 \pm 0 \cdot 02$	$24 \cdot 25 \pm 0 \cdot 69$	$0 \cdot 95 \pm 0 \cdot 01$	$26 \cdot 05 \pm 0 \cdot 55$	$0 \cdot 93 \pm 0 \cdot 01$

SUMMARY

The effects of cultural factors and the two types of nitrogen (organic and inorganic) on the growth and yield of *boro* paddy are reported in this paper.

The best time for planting for grain yield is from the end of December to the middle of January, as the yield deteriorates with the delay in planting, and the closest spacing (four inches both ways) gives the highest yield of grain, six-inch spacing coming next and nine-inch spacing giving the lowest yield. For straw yield, the fourth date of planting, i.e., the middle of January gives the maximum yield with a four-inch spacing.

An average of three years' results shows that organic manure when applied as mustard cake at the rate of 80 lb. nitrogen per acre during the final puddling gives the highest yield of grain, followed by ammonium sulphate as inorganic manure, the increase being 50·5 and 36·6 per cent, respectively, over no-manure.

There is no marked difference in tillers, ear-emergence and length of earheads between treatments, while plant height and length and breadth of the flag are found appreciably higher in manured plots, the response being the greatest with ammonium sulphate.

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GROWTH, DEVELOPMENT AND MINERAL UPTAKE IN TOMATO PLANTS, AS AFFECTED BY MALEIC HYDRAZIDE

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Induction of various changes in plants by the use of growth regulators is not unknown to plant science. The visible changes induced in morphology, growth, maturity and colour by these compounds is also not uncommon. The effectiveness of a growth regulator for inducing a specific response is often conditioned by the degree to which food reserves are available. Hence, this problem was taken to determine the changes in chemical composition of the plant as affected by the use of maleic hydrazide, a potent growth inhibitor, under normal food conditions.

The inhibiting effect of MH on plant growth had been pointed out by Currier and Crafts (1950), Naylor and Davis (1950), Greulach (1951), Carlson (1954), Hamner and Rai (1958) and many others. Greulach (1954) and Arnaud *et al.* (1956) have also shown the differences in amounts of sugars and proteins content as affected by MH treatment, but no one has yet reported the effect of MH on the mineral composition of the plant and as such deserved more attention.

MATERIAL AND METHODS

Tomato plants, variety John Baer, were sown in pots containing quartz sand, under Plant Science Greenhouse conditions (average temperature 60° F, and average day-length 10:42 hours) at the Michigan State University, East Lansing, Michigan, U.S.A. Only one foliar spray of MH in 10, 50 and 100 ppm. concentrations was given to plants at six to seven-leaf stage. Hoagland and Arnon (1950) solution was used as a source of nutrient supply, throughout the experiment.

These plants were grouped and distributed evenly so that the difference in their physiological maturity ceases to be an influencing factor in the results. All treatments were randomized and replicated twice in such a manner that each replicate consisted of four plants.

The mineral analyses of the whole plant were made. Nitrogen was determined by the Standard Kieldahl method and potassium determinations were made by flame-photometer (see *Official Methods of Analysis*, 1955), while phosphorus, calcium, magnesium, iron, boron, manganese, copper and zinc were determined spectrographically.

Periodic observations were recorded for: visual examinations, height, stem diameter, number of leaves, size of the largest leaf, fresh and dry weights of tops and roots.

The mineral accumulation figure of each element per plant were obtained by the

formula:

$$\text{Total amount of each mineral present per plant} \doteqdot \frac{\text{Average dry weight per plant} \times \text{Average per cent mineral present}}{100}$$

Differences between the plant mineral content of any two dates will give the amount of mineral uptake for that period.

OBSERVATIONS

The plants were visually examined. One week after the treatment, leaves of treated plants started to turn darker green in colour. After the second week, the leaves of 50 and 100 ppm.-treated plants appeared very dark green in colour, brittle and thicker and remained the same way throughout the experiment, whereas the 10 ppm.-treated plants showed slightly darker leaves than controls which from third week onwards looked like normal ones.

The treated plants appeared inhibited in growth. The inhibition appeared greater with increase in concentration. The 10 ppm.-treated plants exhibited an abnormal growth, like that of 2, 4-D injury, between the second and third weeks of treatment, but later bloomed like the control plants, whereas 50 and 100 ppm.-treated plants did not bloom at all.

After two weeks of MH application, all treated plants showed a great inhibition in their root growth. Four weeks after the treatment, only 10 ppm.-treated plants showed normal rooting and were much bigger in size than 50 and 100 ppm.-treated plants.

All the growth measurements and mineral determinations have been recorded and their statistical analysis was carried out to find the existing differences between them.

From growth measurements, it is very clear that the growth was less in treated plants than the control, except for the number of leaves which was higher in the 10 ppm.-treated plants (Table I). A significant increase in the 10 ppm.-treated plants over 50 and 100 ppm.-treated plants existed. No significant differences were found between 50 and 100 ppm.-treated plants.

TABLE I. AVERAGE GROWTH MEASUREMENTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Measurements	Treatments*				L. S. D. for treatments	
	Control	10 ppm.	50 ppm.	100 ppm.	5 per cent	1 per cent
a. Height (in cm.)	33·4	30·5	19·4	19·2	2·5	4·5
b. Stem diameter (in mm.)	5·27	4·62	4·35	4·31	0·18	0·33
c. Number of leaves	10·5	11·2	6·7	6·8	1·3	2·4
d. Size of the largest leaf (in cm.)	21·5	19·7	15·2	15·4	3·3	6·1

*All measurements are averages from five observations of two replicates having four plants each.

In the weight of fresh tops and roots, a significant decrease was found in all the treated plants as compared to control (Table II). A significant increase was found in 10 ppm.-treated plants over 50 and 100 ppm.-treated plants. Similar statistical differences were also found in weights of dry tops and roots, except that dry weight of roots of plants treated with 50 ppm. was significantly greater than the 100 ppm.-treated ones.

TABLE II. AVERAGE FRESH AND DRY WEIGHT OF TOPS AND ROOTS OF TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Measurements (gm.)		Treatments				L.S.D. for treatments	
		Control	10 ppm.	50 ppm.	100 ppm.	5 per cent	1 per cent
Fresh tops	I	20·8	11·8	9·9	9·7		
	II	58·7	42·7	12·5	14·9		
	*	39·7	27·2	11·2	12·3	8·1	12·0
Fresh roots	I	3·3	1·6	0·8	1·2		
	II	11·5	9·6	3·4	2·8		
	*	7·4	5·6	2·1	2·0	1·7	2·5
Dry tops	I	1·5	1·0	1·2	1·4		
	II	5·9	4·2	1·9	2·0		
	*	3·7	2·6	1·5	1·7	0·7	1·1
Dry roots	I	0·5	0·3	0·2	0·2		
	II	2·2	1·9	0·8	0·5		
	*	1·3	1·1	0·5	0·3	0·1	0·3

I Average of two replicates having four plants each taken from observations two weeks after the treatment.
II Average of two replicates having four plants each taken from observations four weeks after the treatment.
* Average of I and II.

The average per cent of each of ten mineral elements based on plant's dry weight has been recorded (Table III). Statistical comparisons of individual treatments for each of the mineral elements analysed show no significant differences between 10 ppm.-treated plants and controls except for potassium which was significantly lower in the 10 ppm.-treated plants. All elements were significantly less in the 50 ppm.-treated plants than in 10 ppm.-treated one, except for magnesium and zinc where no significant differences existed. No significant differences were found between the 50 and 100 ppm.-treated plants, except for phosphorus, magnesium and zinc where a significant decrease was found in the 100 ppm.-treated plants over the 50 ppm.-treated ones.

The average amount of mineral uptake in two weeks per plant has been recorded in Table IV. Efficiency of the mineral uptake was calculated on the assumption that controls had 100 per cent efficiency.

TABLE III. AVERAGE PER CENT MINERALS PRESENT IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Minerals	Treatments*				L.S.D. for treatments	
	Control	10 ppm.	50 ppm.	100 ppm.	5 per cent	1 per cent
Nitrogen	3·67	3·59	3·12	3·11	0·19	0·28
Phosphorus	0·17	0·16	0·14	0·13	0·01	0·02
Potassium	5·30	4·89	3·81	3·84	0·17	0·25
Calcium	3·37	3·66	2·79	2·51	0·36	0·54
Magnesium	0·67	0·67	0·62	0·55	0·06	0·08
Iron	0·0309	0·0302	0·0200	0·0201	0·0039	0·0058
Boron	0·0029	0·0027	0·0023	0·0020	0·0003	0·0004
Manganese	0·0035	0·0033	0·0026	0·0027	0·0004	0·0005
Copper	0·0029	0·0025	0·0020	0·0019	0·0005	0·0007
Zinc	0·0057	0·0047	0·0041	0·0037	0·0014	0·0020

*All values are averages from two observations of two samples each.

TABLE IV. AVERAGE MINERAL UPTAKE IN TOMATO PLANTS, AS AFFECTED BY VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Minerals		Average uptake				Efficiency**			
		Control	10 ppm.	50 ppm.	100 ppm.	Control	10 ppm.	50 ppm.	100 ppm.
Nitrogen (mg.)	I	58·5	28·8	27·7	31·5				
	II	180·5	134·2	23·6	19·0				
	*	119·5	81·5	25·6	25·2	100	68·2	21·4	21·1
Phosphorus (μg.)	I	2705	1182	1332	1417				
	II	9450	6813	1058	569				
	*	6077	3997	1220	993	100	65·7	20·1	16·3
Potassium (mg.)	I	91·7	37·1	29·9	37·6				
	II	230·5	190·6	30·4	18·8				
	*	161·1	113·8	30·1	28·2	100	70·6	18·5	17·5
Calcium (mg.)	I	53·1	28·9	20·4	20·5				
	II	164·0	146·1	30·4	19·9				
	*	108·5	87·5	25·4	20·2	100	80·6	23·4	18·6
Magnesium (μg.)	I	1035	519	561	512				
	II	3471	2538	522	399				

TABLE IV. (*Contd.*)

Minerals		Average uptake				Efficiency**			
		Control	10 ppm.	50 ppm.	100 ppm.	Control	10 ppm.	50 ppm.	100 ppm.
	*	2235	1528	541	455	100	67·8	24·1	20·2
Iron (μg.)	I	560	288	185	222				
	II	1309	1035	88	38				
	*	934	661	136	130	100	70·8	14·7	13·9
Boron (μg.)	I	50	25	25	23				
	II	140	106	14	8				
	*	95	65	19	15	100	68·4	20·0	15·8
Manganese (μg.)	I	58	22	17	25				
	II	135	117	16	5				
	*	96	69	16	15	100	71·9	16·7	15·6
Copper (μg.)	I	53	25	18	22				
	II	128	77	17	0				
	*	90	51	17	11	100	56·7	18·9	12·2
Zinc (μg.)	I	87	26	33	21				
	II	292	204	26	41				
	*	189	115	29	31	100	60·8	15·3	16·3

I Average uptake of two samples taken two weeks after treatment.
II Average uptake of two samples taken four weeks after treatment.
* Average uptake of 1 and II.
** Calculated on the basis that controls (*) are 100 per cent efficient.

It was found that the efficiency of the 10 ppm.-treated plants ranged from 56·7 to 80·6 per cent; for 50 ppm., it ranged from 14·6 to 24·1 per cent, and for 100 ppm., it ranged from 12·2 to 21·1 per cent. The efficiency of mineral uptake in tomato plants decreased with increase in concentration of maleic hydrazide applied.

DISCUSSION

In the field of plant growth inhibiton, maleic hydrazide (MH) has come to occupy an important place. Studies conducted in all parts of the world indicate that this compound has transitory inhibiting effects on bud development and growth of various plant species. When applied in suitable concentrations, it slows down the plant metabolism, resulting in almost a complete stoppage of growth. Such was the case when 50 and 100 ppm. applications were made on tomato plants of the variety John Baer, while the low rate application had a temporary inhibiting effect.

The growth resumed in the plants treated with 10 ppm. MH concentration shortly after two weeks and these had an appearance of a normal plant which did not receive any application of the compound. Such a growth pattern is entirely possible for, according to Leopold and Klein (1952), inhibition of growth by low concentrations of MH is completely relieved by the addition of auxin. Since the 10 ppm. concentration failed to induce any outstanding inhibition, it is logical to assume that auxin production continued uninterrupted or after a brief interruption in the meristematic tissue of the plant. These auxin levels which keep on building up in the plant system finally make it possible for the low rate treated plants to recommence their growth.

According to Callaghan and Van Norman (1956), there is an increase in the photosynthetic rate at low rate MH application in swiss chard and tobacco seedlings accompanied by little or no change in dry matter. This type of induced physiological modification may as well, in some way, be responsible for the early renewal of growth in the plants with 10 ppm. concentration.

Such an explanation for the resumption of growth in the low-rate-treated tomato plants appears logical when the mineral uptake is considered to be a factor in the development of plants. The data indicated (Table IV) that the mineral uptake of plants was significantly different for the low-rate-MH-treated plants as compared to the plants which received 50 and 100 ppm. applications. It is interesting to point out that the mineral uptake in the 10 ppm.-treated plants was much higher than the 50 and 100 ppm.-treated plants during the last two weeks, whereas practically no difference existed in the first two weeks of the treatment. However, it may be brought out that these non-existing differences were nevertheless present after MH treatments, during early sampling dates.

Therefore, it is safe to state that low-rate MH applications do not bring about any changes in the physiological developments of the plants to any significant level which may tend to shift the natural metabolic balances. It is evident that root development was inhibited by all concentrations of MH two weeks after the treatment (Table II). The degree of growth inhibition was significantly different for the low-rate application of 10 ppm. as compared to the 50 and 100 ppm. treatments after four weeks from the application date. Roots being more sensitive than the shoots, therefore, there was wide range of difference in the growth pattern of roots and shoots. These findings are in conformity with the views of Compton (1952).

High-rate application of the compound, 50 and 100 ppm., on the other hand, affected the growth processes of the plants to a point of severe growth inhibition. This fact is borne out by the data; height, stem diameter, number of leaves and size of the largest leaf of the plants, (Table I). The growth suppression, as noticed in these treatments, may be due to inhibition in the plant tissue resulting from the high rate of MH applications. Such a possibility has been mentioned by Naylor and Davis (1951) and Greulach (1954), who observed from their experiments on a wide variety of vegetation that the respiratory changes exert influence on the normal function of dehydrogenase. However, it is not possible to say how this induced malfunctioning in the developmental physiology of the plant affects the growth manifesting mechanism.

SUMMARY

A continued inhibition of growth was observed in plants receiving 50 and 100 ppm. foliar applications, while 10 ppm. MH concentration exhibited only temporary growth inhibition. The leaves of plants treated with 50 and 100 ppm. MH were dark green in colour, thicker and more brittle. Following the temporary inhibition of growth, the plants treated with 10 ppm. indicated some abnormality in the morphological character, shape and branching, in comparison with the control, plants which had less leaves. There was no sign of flower initiation in plants treated with 50 and 100 ppm. concentrations.

Plants receiving a high rate of treatment, 50 and 100 ppm., produced growth of low fresh and dry weights. Root growth was much reduced in the treated plants as compared to top growth which indicated roots to be very sensitive to the treatments. Plant tissue analysis indicated that mineral content, per cent composition and mineral uptake of all the elements, on an average, decrease on account of the treatments.

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STUDIES ON SPACING OF *CAJANUS CAJAN* (L.) MILLSP.

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Cajanus cajan (L.) Millsp., commonly known as *arhar* in northern India and *tur* in the Deccan Plateau, is one of India's important pulses, being second only to *Cicer arietinum* (gram). In West Bengal, it occupies an area of 57,000 acres, the total production being 15,000 tons, and the average yield of the crop about 7·16 maunds per acre. Apart from its higher yield and immense food value, *arhar* finds a prominent place in crop rotation and crop mixtures by virtue of its being a leguminous crop.

Improvement work on this crop was taken up in India as early as 1905 by the Howards, and since then a large number of improved varieties have been evolved and distributed to the cultivators to step up its production. Previous improvement work was, however, mainly confined to the evolution of high-yielding strains, and much attention does not seem to have been paid towards the study of agronomic practices like time of sowing, effect of spacing and intercultural operations.

In most *arhar*-growing tracts, particularly in West Bengal, the crop is sown broadcast—the age-old method followed for so many other crops. However, the recent experiments on various crops have definitely shown that line-sowing is better than broadcast sowing, not only in reducing the cost of cultivation, but in increasing the yield as well. In the States of Bombay, Madhya Pradesh, Bihar and Uttar Pradesh, *arhar* is, however, generally sown in lines. In Central India and Madhya Pradesh, a spacing of 14 to 16 inches between rows has been found to give better yields. In Uttar Pradesh and Bihar, spacings of 18 to 36 inches between rows are recommended. The spacings between plants have, however, been found to vary from 12 to 24 inches, depending on the fertility of the soil (*Wealth of India*, 1950).

Krauss (1921) observed a spacing of four to five feet between the rows and six inches between the plants to give a better seed crop under Hawaiian conditions.

Although the area under *arhar* in West Bengal cannot be increased to any great extent due to obvious reasons, its production can be increased by growing high-yielding varieties, adjusting the time of sowing of the crop and adopting other improved methods of cultivation. It is with this end in view that a study on the effect of different spacings on the yield of *arhar* was undertaken along with the work on the evolution of high-yielding types, under the Scheme for Research on Pulses in West Bengal, financed jointly by the Indian Council of Agricultural Research and the State Government. The experiment was undertaken in *kharif* 1952-53 at the State Agricultural Farm, Berhampore (Murshidabad), and continued up to 1956-57.

MATERIAL AND METHODS

Arhar Type-7, an improved variety evolved at Berhampore, and yielding about 18 to 20 maunds per acre under Berhampore conditions, was grown in the experiment.

The experiment had seven treatments, and was laid out in randomized blocks with four replications. The treatments (spacings) included were: (i) 2 ft.×2 ft. (ii) 2 ft.×3 ft. (iii) 2 ft.×4 ft. (iv) 3 ft.×3 ft. (v) 3 ft.×4 ft. (vi) 4 ft.× 4 ft. (vii) broadcast. The area of each plot was 1/151·25th acre. The sowing was done by dibbling three to four seeds per hole in all the treatments that were sown in lines (treatments i to vi). In the case of the last treatment, viz., broadcast-sowing, the plots received a seed-rate of 12 pounds per acre, which is the cultivators' practice in the region. These plots were later thinned out keeping the plants at an approximate distance of one foot from each other. Only one plant per hole was ultimately retained in each line-sown plot. The yield data of each individual plot was recorded in *chhataks*.

RESULTS

The yield data of each individual year were analysed. Significant results were obtained in four out of five seasons the experiment was conducted. The mean yields per acre and the necessary statistical values are presented in Table I.

TABLE I. YIELD, S.EM AND C.D. IN MAUNDS PER ACRE TOGETHER WITH F VALUE FOR INDIVIDUAL YEAR

Spacing (in ft.)	Yield in md. per acre				
	1952–53	1953–54	1954–55	1955–56	1956–57
2×2	28·06	38·41	31·32	16·61	14·53
2×3	24·69	25·13	30·73	12·65	10·10
2×4	23·56	33·98	30·90	15·37	8·57
3×3	26·58	21·83	29·01	11·94	8·63
3×4	23·22	18·05	28·37	13·12	7·86
4×4	17·36	14·46	22·22	12·70	5·32
Broadcast	26·70	27·67	18·97	15·01	11·23
F value	5·39**	4·73**	2·96*	0·86	6·12**
S.Em	± 1·52	± 3·91	± 2·81	± 1·87	± 1·17
C.D. at 5%	4·53	11·63	8·35		3·48
C.D. at 1%	6·20	15·94	..		4·77

**Significant at one per cent level.
*Significant at five per cent level.

From Table I, it is evident that the spacing 2 ft.×2 ft. gave the highest yield in all the five seasons. But the yield obtained from the spacing was significantly higher than broadcast-sowing only in 1954-55, while in 1953-54 and in 1956-57, the superiority of the 2 ft.×2 ft. spacing just missed the five per cent level of significance. In 1955-56,

the results were not significant. The average yield also varied with the seasons. Since there were some fluctuations in the results of the experiment in different crop seasons, it was considered necessary to analyse the pooled data to find out the overall effect of different spacings on yield, as also to study the consistency of the effects of different treatments. The results of the pooled analysis are given in Table II.

TABLE II. ANALYSIS OF VARIANCE OF POOLED DATA (FIVE YEARS)

(in *chhataks* per plot)

Source	D.F.	S.S.	Variance	F
Block	3	817·17	272·39	..
Treatment	6	26,828·34	4,471·39	10·25**
Seasons	4	1,26,877·31	31,719·33	72·75**
Treatment × Season	24	24,684·59	1,028·52	2·36**
Block × Season	12	3,693·26	307·77	..
Error	90	39,241·07	436·01	..
Total	139			

**Significant at one per cent level.

It is clearly seen (Table II) that the overall effect of treatments is highly significant, indicating that the yield differences due to different treatments are quite large. It is, however, yet to be seen if a particular spacing would give a significantly higher yield than broadcast-sowing. The average yields from all the five years have been tabulated in Table III and from the data presented there it could be seen that the yield obtained from the 2 ft.×2 ft. spacing is significantly higher than any of the spacings and broadcast-sowing at five per cent level of significance.

TABLE III. MEAN YIELD, S.EM AND C.D. IN MAUNDS PER ACRE

Spacing	Yield	S.Em.	C.D.	
			at 5 per cent	at 1 per cent
2 ft. × 2 ft.	25·80			
2 ft. × 4 ft.	22·48	± 1·1	3·1	4·11
2 ft. × 3 ft.	20·57			
Broadcast	19·92			
3 ft. × 3 ft.	19·60			
3 ft. × 4 ft.	18·12			
4 t. × 4 ft.	14·41			

Table III reveals that the yield obtained from broadcast-sowing is significantly lower than the yield obtained from the 2 ft. × 2 ft. spacing and significantly higher than the yield obtained from the 4 ft. × 4 ft. spacing at both five per cent and one per cent levels of significance.

It is seen in Table II that the 'F' value for the interaction treatment × season is also significant at one per cent level. This means that the effects of different spacings vary in different seasons. Nevertheless, the yield trends were fairly consistent in different years and the 2 ft. × 2 ft. spacing did give the highest yield in all the seasons, as would be evident from the graph presented in Fig. 1.

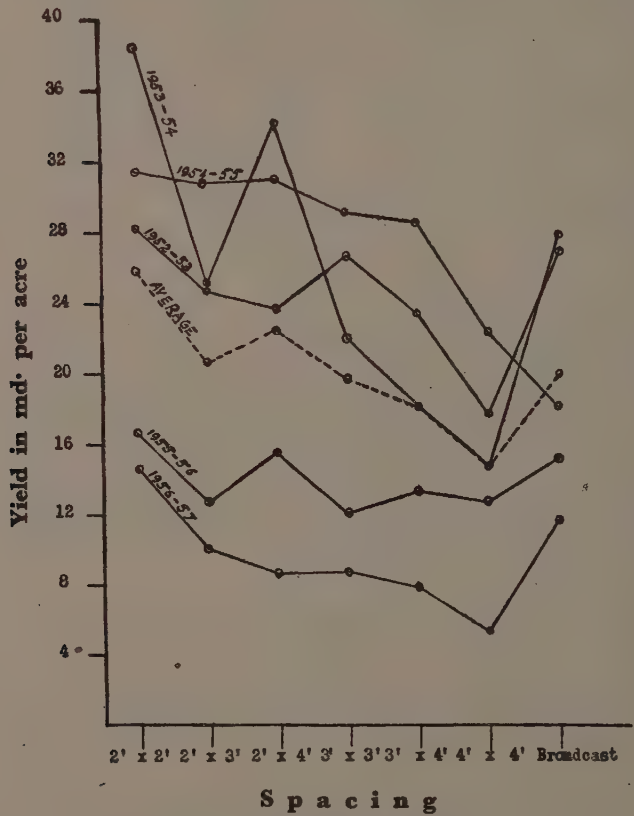

Fig 1. Graph showing the effects of spacings on yield of *Cajanus* in different years

The variance ratio for 'seasons' is rather very high (72·75), indicating that very large seasonal effects are present. Since the experiments were conducted at the same location with the same variety and layout, it is obviously the climatic conditions that came into play in bringing about the seasonal differences. *Cajanus cajan* being a *kharif*

crop, its growth much depends on the rainfall and temperature. During its developmental stages, the crop is susceptible to frost and extreme low temperature. Except the district of Darjeeling, West Bengal does not, however, experience extreme low temperature or frost. It is, therefore, the rainfall data that require an examination. The rainfall as recorded at Berhampore farm is given in Table IV.

TABLE IV. RAINFALL IN INCHES (AT BERHAMPORE FARM)

Month	1952	1953	1954	1955	1956	1957
January	..	2·30	0·50	0·52	0·11	3·80
February	0·06	0·27	0·18	0·22	0·44	1·08
March	1·77	0·06	..	1·05	0·85	0·18
April	4·20	0·11	0·03	1·11	0·36	
May	1·37	2·62	1·60	2·79	4·39	
June	11·44	12·05	14·44	5·25	7·84	
July	17·89	15·10	9·51	23·01	5·08	
August	10·42	6·90	11·03	13·59	6·83	
September	8·54	7·61	4·87	2·63	14·09	
October	7·06	0·20	2·77	2·50	4·51	
November	..	0·43	..	1·73	0·36	
December	..	..	0·16	..	1·20	

It is clear from Table IV that 1955 and 1956 received a very poor rainfall in June, as compared to other years. The crop, in general, is sown in early June, and, as a result of lower rainfall during this month, the crop received an initial setback in its growth. Then, in July, 1955, there was an unusual precipitation which had its adverse effects on the crop. During this year, August also received a rather high rainfall, while September experienced a rainfall much lower than the normal. In 1956, not only June, but July and August also received very poor rainfall, as compared to the other years, and September received an unusually heavy rainfall. In other words, during 1955 and 1956, the distribution of rainfall was uneven, resulting in stunted crop growth. Therefore, the yield figures were very low and the seasonal differences very high, which are indicated by the high 'F' value.

The abnormal climatic conditions of certain seasons affected the crop adversely, with the result that the performance of the different treatments in different years was inconsistent.

The average yields per acre, calculated in Table III, bring out the effects of the different spacings very clearly. The yield of a particular area depends on the number of plants as well as on the yield per plant. In order to study the effects of these two factors, the number of plants per plot and the yield per plant in the case of each spacing

have been calculated and presented in Table V. The number of plants per plot due to broadcast-sowing was found to vary from year to year ranging from 220 to 280 approximately, and an average of 250 plants has been taken for calculations.

TABLE V. YIELD PER PLANT IN *CHHATAKS*

Spacing	No. of plants per plot	Year					Average of five years
		1952–53	1953–54	1954–55	1955–56	1956–57	
2 ft. × 2 ft.	91	1·300	1·790	1·450	0·772	0·676	1·198
2 ft. × 3 ft.	65	1·600	1·600	2·000	0·823	0·658	1·336
2 ft. × 4 ft.	52	1·920	2·770	2·510	1·250	0·700	1·830
3 ft. × 3 ft.	45	2·500	2·060	2·730	1·120	0·810	1·844
3 ft. × 4 ft.	36	2·730	2·125	3·330	1·540	0·920	2·129
4 ft. × 4 ft.	28	2·625	2·190	3·360	1·920	0·800	2·199
Broadcast	250	0·452	0·469	0·321	0·254	0·190	0·337

Table V indicates that the yield per plant is the maximum with a spacing of 4 ft.×4 ft., and minimum with broadcast-sowing. But the average yield per plot is the maximum from a spacing of 2 ft.×2 ft., and minimum from the 4 ft.×4 ft. spacing, that from broadcast-sowing being intermediate (Table III).

DISCUSSION

The overall performance of the different spacings was highly significant and the effects of individual treatments fairly consistent. The ranking of the spacings was, however, not consistent in all the crop seasons, for which climatic conditions, mainly rainfall, seem to have been responsible. However, in each season, the yield due to the 2 ft.×2 ft. spacing was the best. The significant 'F' value for treatment×season indicates that climatic conditions of different crop seasons have different effects on the same spacing. If there is a larger number of plants in a plot, as in broadcast-sowing, and if drought conditions prevail, quite a few plants would be very badly affected, but the plot would still be left with sufficient plants to yield moderately as compared to one where the number of plants per plot is rather small. In the latter case, the adverse effect of drought would be much more pronounced than it would be in the former. This is clear from the results of the experiment conducted in 1956-57. In this year, the months of June, July and August suffered acutely from drought (Table IV). The average yield per acre of broadcast-sowing (1952-53 to 1954-55) was approximately 24·5 maunds and that of the 4 ft.×4 ft. spacing was approximately 18·0 maunds. In 1956-57, the respective yields were 11·2 and 5·3 maunds per acre. While in the former case, the yield obtained in 1956-57 was 45·7 per cent of the average, in the latter it was only 29·4 per cent. In other words, the effect of drought was more pronounced in the plots having a smaller number of plants.

The high 'F' value due to seasonal effects is obvious. Table IV reveals that the rainfall was not uniform in all these five years, and naturally, the growth of the crop was affected differently, thus bringing about a significant difference between the seasonal effects. The average yields of the first three seasons were rather high, while those of the last two seasons were appreciably lower, even lower than the average of the variety used. So far as the Berhampore area was concerned, the last two seasons, in fact, experienced very unfavourable climatic conditions for the growth of *kharif* crops in general.

Table V shows that the average yield per plant increases with an increase in spacing, the maximum being obtained in the 4 ft. × 4 ft. spacing. But the total yield per plot increases with a decrease in spacing, the maximum being obtained with 2 ft. × 2 ft. It is also seen that the decrease in the total yield with increased spacing, despite increased yield per plant, is associated with the reduced number of plants per unit area. Conversely, the maximum yield-potential of a plant is expressed when sufficient feeding area is allowed to it. Exploitation of this maximum plant-yield is, however, associated with a considerable reduction in the number of plants per unit area, resulting in a reduced total yield per plot, and, consequently, reduced yield per acre.

On the other hand, with broadcast-sowing, though the plant population is increased manifold, the yield per plant is reduced considerably due to irregular and smaller spacing. In fact, the loss due to lower individual plant-yield is not compensated for by the larger number of plants. This is obvious, because full growth of plants is never possible due to smaller spacings between them, which adversely affect the different yield attributes, and hence the yield potential remains suppressed. With larger spacing, the yield potential is exploited to the maximum, but the total yield is bound to be lower due to decreased population size per unit area.

Thus, the problem is of selecting such a spacing which would give the best combination of the two, viz., a maximum utilization of the yield-potential and larger population, so that the best possible yield per unit area is obtained. Such a spacing for *Cajanus cajan* has been found to be 2 ft. × 2 ft., because in this case, (i) the yield per plant is not as low as that of plants of broadcast-sowing, although it is not as high as that obtained from a spacing of 4 ft. × 4 ft. The difference between a spacing of 2 ft. × 2 ft. and that of 4 ft. × 4 ft. with regard to single-plant yield is much less than the difference between a spacing of 2 ft. × 2 ft. and broadcast-sowing, and, (ii) the population is of considerable size (larger than all except broadcast-sowing). The result of the combined effect of higher individual-plant yield and larger plant population is plot yield of higher magnitude than any of the extremes and all other intermediates (at five per cent level of significance).

It may, therefore, be said that of the spacings tried in the investigation, two feet between rows and two feet between plants would be the optimum for sowing *Cajanus* in West Bengal. Broadcast-sowing may be avoided on account of its lower yield rate. In fact, a yield of 25·8 maunds per acre was obtained with a spacing of 2 ft. × 2 ft. as against 19·92 maunds obtained from broadcast-sowing, thus giving an increased yield of 5·58 maunds per acre or 29·5 per cent. With this spacing, the seed requirement is only 4-5 lb. per acre as against 10-15 lb. normally used in broadcast-sowing.

Therefore, a substantial saving of seeds is indicated by the results of the experiment. The cost of cultivation is also reduced due to facilities for easy movement between the rows and for using implements instead of manual labour for intercultural operations.

SUMMARY

The present paper deals with the effects of different spacings on the yield of *Cajanus cajan* (L) Millsp. Investigations were undertaken to find out the optimum spacing for *Cajanus* under West Bengal conditions. The experiment was laid out in randomized blocks with four replications and seven treatments (spacings), including the broadcast method of sowing (as control), at the State Agricultural Farm, Berhampore, in 1952-53, and continued for five years (1956-57).

The results indicated that the yield obtained from a spacing of 2 ft. × 2 ft. was significantly higher than any other spacing at five per cent level.

The interaction between ' season ' and ' treatments ' was highly significant, indicating differential response of treatments in different seasons.

Seasonal effects were found to be very pronounced. This was probably due to differential distribution of rainfall in the different crop seasons.

With a decrease in spacing the single plant yield was found to decrease, but the total yield of the plot increased and *vice versa*, up to a limit. With a spacing of 2 ft. × 2 ft., the effect of reduced yield per plant was not only compensated for, but the maximum increase of plot yield was obtained due to larger population size.

The 2 ft. × 2 ft. spacing gave an increased yield of 29·5 per cent over broadcast-sowing.

A substantial saving of seeds has been indicated by the results of the experiment. The cost of cultivation is also reduced.

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ANTHESIS STUDIES IN RAJASTHAN *BAJRA* (*PENNISETUM TYPHOIDEUM*)

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Pearl millet or *bajra* is an important crop in Rajasthan and some parts of western and southern India. It has not received much importance, even though a very large area is covered by this crop. Recent work at Coimbatore and other places has shown that as in maize, the phenomenon of hybrid vigour could be utilized, with considerable advantage, in this crop as well. In Rajasthan, the work done on mass selection on regional basis has yielded valuable results and it is an easy means for quick improvement in this crop. Inbreeding of various types of *bajra* found in Rajasthan has been taken up and the present study on anthesis is a part of that programme. It is hoped that this study will be useful to the future breeding programmes on this crop.

The peculiar mode of anthesis in *bajra* has attracted the attention of several research workers, both in India and abroad, from time to time (Kornicke, 1885; Leeki, 1907; Robinson, 1917; Fruwirth, 1923; Godbole, 1927; Patwardhan, 1927; Burns and Barve, 1932; Ayyanger, 1933; Aziz *et al.*, 1956). The present observations were made under south Indian conditions, and for studying anthesis under north Indian conditions, especially Rajasthan, the work was carried on at the Botanical Research Station, Durgapura.

MATERIAL AND METHODS

Bajra T.5, the standard variety for some parts of this State, was selected for this study. The method consisted in selecting earheads of suitable stages at random in the field and observations were recorded daily or hourly as and when required. The temperature and humidity data were taken from the Central Meteorological Station situated near the farm.

OBSERVATIONS

Inflorescence: It is a terminal panicle six to 18 in. long, sometimes even more, as in the Jamnagar Giant variety. It has a prominent axis covered with fine white velvety hairs. The central axis bears rachilla which ultimately bears a pair of spikelets. Each spikelet consists of two florets, the lower staminate and the upper bisexual. Each spikelet is surrounded by a number of bristles which in some cases are very prominent; their number varies from strain to strain, and even from plant to plant in the same strain. Each floret has a prominent lemma and a hyaline palea, three stamens, and a single style, which on full emergence is forked in its upper parts and possesses stigmatic hairs over its surface, each of the latter being capable of admitting pollen tubes. The lodicules are absent.

Emergence of spike from the sheath: The spike took six days to emerge fully from the leaf sheath. In a few cases, it did not emerge completely even after its maturity.

TABLE I. TIME TAKEN BY THE SPIKE TO EMERGE FROM THE SHEATH

(Total of 20 spikes)

No. of days	4	5	6	7	8	9	10	11	Total No. of spikes
Frequency of spikes	3	4	9	3	..	..	..	1	20

The emergence of the spike (Fig. 1) was accomplished by rapid elongation of the peduncle and also the internode below it. The rate of emergence increased till the fifth day. Later it showed a sudden fall. The maximum emergence was recorded on the 5th day.

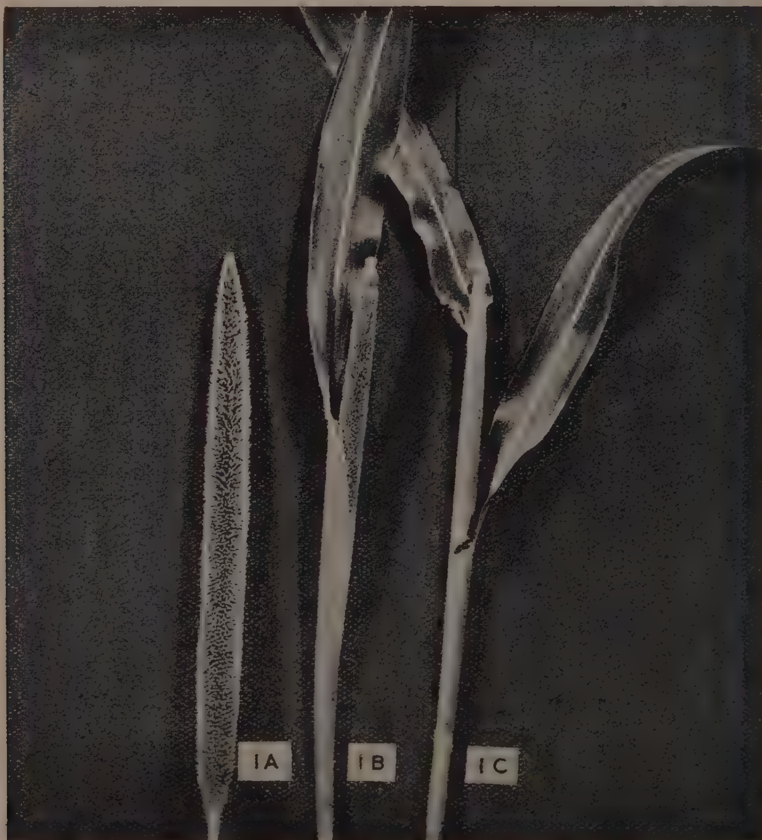


FIG. I. (B & C) EMERGENCE OF SPIKE FROM THE SHEATH AND THE FIRST FLUSH OF STIGMA (I A)

Anthesis: It was observed that anthesis always began when the spike was still within the sheath. Full emergence of spike, if at all, took place after about two or three days of the initiation of the anthesis.

TABLE II. NUMBER OF DAYS REQUIRED BY THE SPIKE TO EMERGE FROM THE SHEATH AFTER ANTHESIS BEGINS

No. of days	1	2	3	4	5	6	7	8	No. of spikes which do not come out of sheath	Total No. of spikes
Frequency of spikes	4	8	9	2	3	1	..	1	4	32

Out of the thirty-two spikes examined, not a single case was found in which anthesis started after their full emergence of a spike from its sheath. On account of the pronounced protogynous condition of the perfect flower, the gynoecium matures first followed by androecium. Anthesis, (Figs. I A and 2) took place in three flushes, each flush overlapping the other. The first flush was of stigma while the second and third were of stamens. Anthesis lasted for about nine days on an average, but this period varies from seven to nine days.

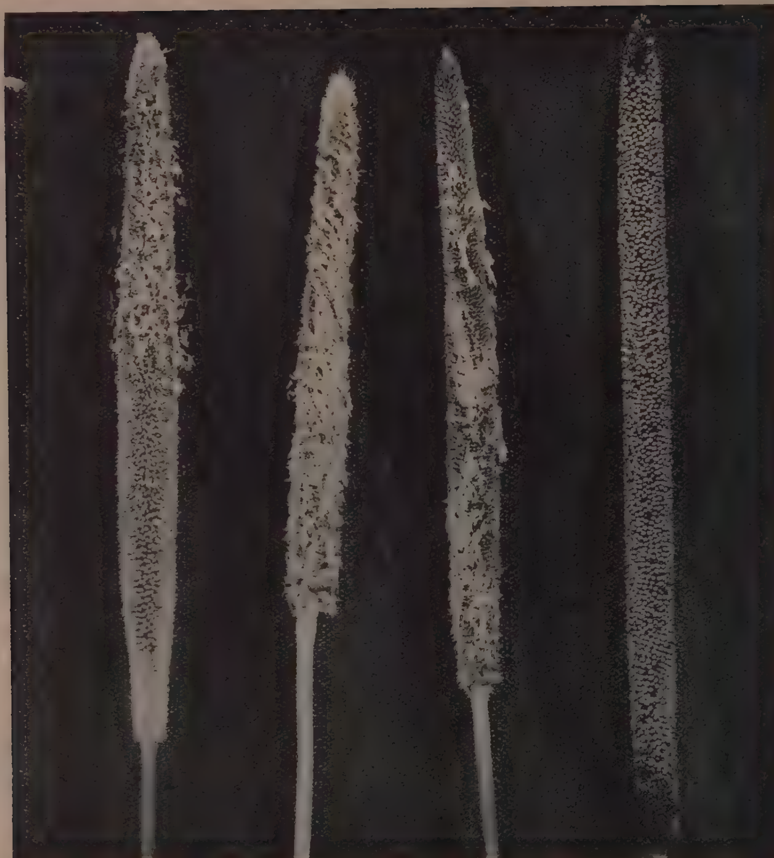
TABLE III. PERIOD OF ANTHESIS

No. of days	7	8	9	10	11	12	Total No. of spikes
Frequency of spikes	2	8	10	5	5	2	32

Gynoecium: Immediately on maturity, the style was observed to elongate with the result that the tip of stigma, which up to this time was hidden inside the glume, was seen coming out. The feathery stigma at the time of emergence remained nearly united. It was after they fully came out of the glumes, that the forking took place. The stigma took a long time to protrude and open. It took from five to seven hours from the time their tips were seen till they totally separated from each other assuming a forked condition.

TABLE IV. TOTAL HOURS TAKEN BY THE STIGMA IN FULLY COMING OUT OF GLUMES IN FORKED CONDITIONS

No. of hours	5	6	7	Total No. of flowers
Frequency of flowers in different spikes	4	8	22	34



A B C D

FIG. 2. A-D. VARIOUS FLUSHES OF ANTHERS LEADING TO GRAIN FORMATION IN THE SPIKE A, FIRST FLUSH (BEGINNING); B, FIRST FLUSH (END); C, SECOND FLUSH (INITIATION OF GRAIN FORMATION); D, COMPLETE GRAIN FORMATION

The style, after assuming the forked condition of stigma, continues to elongate, attaining a maximum length of 4·5 to 7·5 mm. The stigmas remain fresh and capable of being pollinated for a period varying from 18 to 21 hours.

TABLE V. TOTAL PERIOD OF RECEPTIVITY OF STIGMA AFTER IT COMES OUT OF GLUMES AND ASSUMES A FORKED CONDITION

No. of hours	18	18½	19	19½	20	20½	21	Total No. of flowers
Frequency of flowers in different spikes	4	..	4	2	8	8	8	34

After that the stigma began to fade. Immediately after its emergence, a sugary shining coating was visible, which indicated its immediate receptivity. The styles between 1/10th to 1/4th of the total length of the spike from its tip were the first to come out.

TABLE VI. EXACT POSITION OF EMERGENCE OF FIRST STIGMA FROM TIP OF THE SPIKE

Exact position from the tip of spike	Fraction of the full length of spikes from its tip								Total No. of spikes
	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	
Frequency of the spikes	2	4	5	..	4	3	..	1	19

Anthesis thereafter spread upwards and downwards from the point where the first style came out. The period required for full emergence of style, from the tip to the base of the spike, varied from one to five days, usually two days in most cases.

TABLE VII. NUMBER OF DAYS TAKEN BY THE STYLES FOR COMPLETE EMERGENCE THROUGHOUT THE EARHEADS

No. of days	1	2	3	4	5	Total No. of spikes
Frequency of the spikes	5	16	5	5	2	33

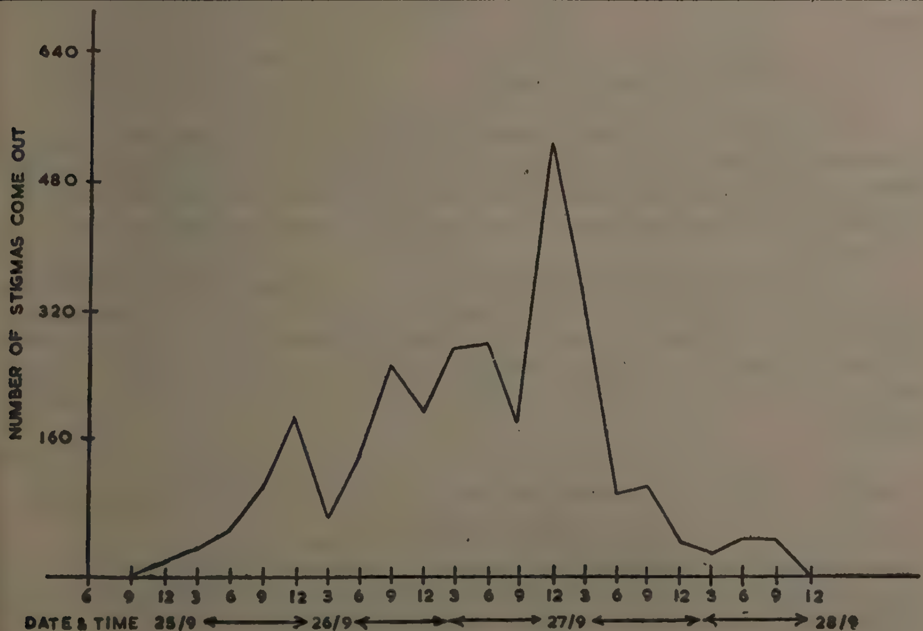


FIG. 3. PERIODIC EMERGENCE OF STYLES

Emergence of styles continued throughout the 24 hours under all conditions, rainy or not. The maximum number of styles emerged between 9 a.m. and 3 p.m. during the day (Fig. 3.) Early morning and late evening hours were dull periods, the peak period being 12.00 hours of the second day, beyond which there was a continuous declension in the number of emerging stigmas.

TABLE VIII. TOTAL NUMBER OF STYLES COMING OUT AFTER EVERY THREE HOURS FROM 11-9-54 TO 14-9-54

Time	Dates			
	11/9	12/9	13/9	14/9
3 a.m.	..	78	233	23
6 a.m.	..	60	286	42
9 a.m.	..	107	189	39 Conservations were finished
12 noon	..	205	543 (Peak hrs.)	
3 p.m.	..	66	360	..
6 p.m.	..	147	97	..
9 p.m.	..	247	108	..
0 hr.	20	198	41	..

NOTE: The forked stigmas were only counted.

Before this first flush of styles was completed, at the base of the spike, the emergence of the stamens from the perfect flowers started. It was seen that the first stamen under normal conditions emerged mostly two or three days after the first stigma came out of the glumes. In exceptional cases, it took as many as five days or even one day only (Table IX).

The fact that the first flush of stamens is always overlapping the first flush of stigmas is of great importance in determining the extent of cross or self-pollination. The greater the overlapping period the greater the chances of self-pollination, and *vice versa*. A variety with no overlapping period is definitely 100 per cent cross-pollinated, and as such exploitation of hybrid vigour in such a variety is much more easy.

TABLE IX. NUMBER OF DAYS WHEN THE FIRST STAMENS COME OUT AFTER THE EMERGENCE OF THE FIRST STIGMA

No. of days	1	2	3	4	5	Total No. of spikes
Frequency of spike	2	14	14	1	1	32

Androecium: Overlapping the first flush of stigmas, the second flush of stamens started. The first anthers came out somewhere near the tip of the spike. The exact position varied from tip up to 1/5th of its total length. In rare cases, it was observed that the first anther came out even up to 1/3rd of the length of the earhead from its tip (Table X).

TABLE X. EXACT POSITION OF EMERGENCE OF THE FIRST STAMEN FROM THE TIP OF THE SPIKE

Position from the tip of the spike	Fraction of the earhead														
	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{9}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{12}$	$\frac{1}{13}$	$\frac{1}{14}$	$\frac{1}{15}$	Tip	Total
Frequency of the spikes	1	..	9	1	2	..	1	2	..	..	..	1	1	7	25

The anthesis thereafter spread in both the directions. When it started at the tip, it followed downwards; but when it started from below the tip, it travelled in both directions. The complete cycle of emergence of stamens in a spike was full of ups and downs. It was at the peak on 4th and 5th days, followed by a sharp fall up to eighth day. Thereafter, it declined with slow rise and fall, till it ended completely.

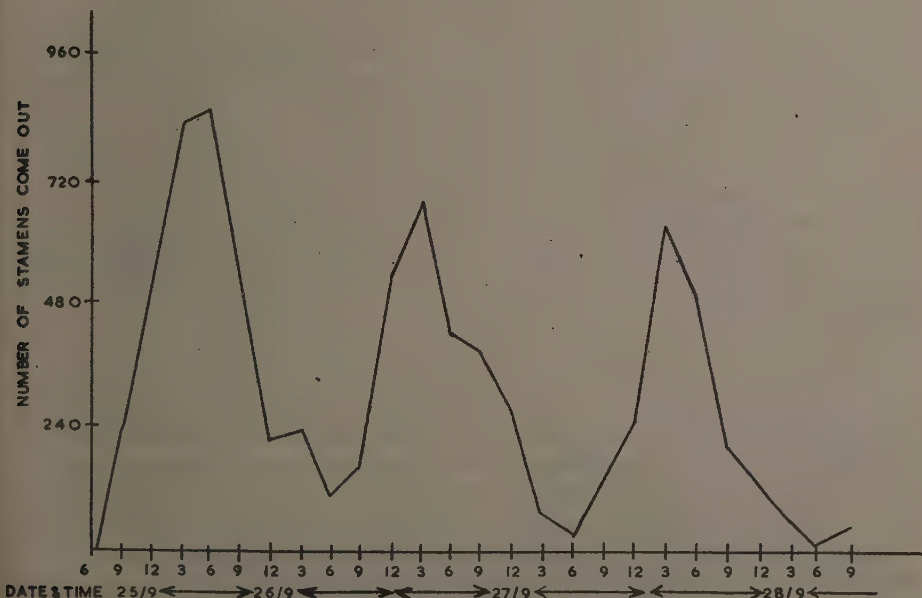


FIG. 4. PERIODIC EMERGENCE OF STAMENS

The blooming continued throughout the 24 hours. Even under torrential rains in the night and day, it did not cease. The maximum number of stamens came out between 0 hours to 8.0 a.m. when there was low temperature and high humidity (Fig. 4). There seemed to be no correlation between other weather conditions like sunshine, cloudiness, raining, etc., and emergence of stamens (Tables XI and XII).

TABLE XI. NUMBER OF STAMENS COMING OUT AFTER EVERY THREE HOURS FROM 25-9-54 TO 28-9-54

(Total of six earheads)

Time	Dates				
	25/9	26/9	27/9	28/9	
3 a.m.	..	830	694	641	Peak hrs.
6 a.m.	..	861	434	486	
9 a.m.	..	427	390	229	
12 noon	..	215	268	121	
3 p.m.	..	239	65	65	
6 p.m.	Observation started	98	19	17	
9 p.m.	240	165	141	37	
0 hr.	505	540	250	..	

TABLE XII. WEATHER CONDITIONS

	25-9-54	26-9-54	27-9-54	28-9-54
Day	Sunshine, no clouds	Cloudy with intermittent sunshine	Bright sunshine, no clouds	Cloudy and rainy, no sunshine during the whole day
Night	Sky clear	Sky clear, occasional clouds	About C. 1·5 in. rain, clouds all the night long	

Observations taken on a cloudy day and night, rainy day and night, hot bright sunny day, and clear cool night showed that blooming went on uninterrupted.

Although emergence of stamens continued all the day and night, its rate was never constant. The rate seemed to be positively correlated with humidity (value being ×0·77) while negatively correlated with the temperature (value being —0·87). Both these values are highly significant under field conditions.

The stamens usually took four to nine or even twelve days in completing their full emergence throughout the panicle.

Table XIII. Number of days taken by stamens in finishing the emergence throughout the earhead

No. of days	4	5	6	7	8	9	10	11	12	Total No. of earheads
Frequency	3	3	10	7	4	4	..	..	1	32

Stamens of the bisexual flowers were the first to emerge. There were generally two flushes of the stamens. In the first flush, emergence of the stamens from the bisexual flowers took place throughout the length and breadth of the spike, except its base. Again, before this flush was completed at the base, the second flush of the stamens from staminate flowers started from tip downwards, thus always overlapping the first flush. The second flush continued up to one or two days before the grain formation was completed. In exceptional cases, it was seen that stamens emerged from unisexual flowers even after grain formation was completed.

Emergence of Anthers

In a single floret, the tip of the anther was the first to become visible. It was noticed that sometimes one anther, or at times all the three, emerged from the glumes simultaneously. In clear sunshine, generally the time taken by the anther to emerge fully from the glumes varied from 15 to 20 minutes, or sometimes more. The filaments at the same time elongated. Due to the universal absence of lodicule, there was no pushing force as in the case of wheat and other crops which helped stamens in their emergence. According to Ayyanger (1933), penicillate anthers seem to be a special adaptation for the slow and laboured emergence of the anthers lacking lodicule facilities for glume opening.

Dry bright weather favoured the shedding of the pollen while cold and wet conditions delayed it. During rainy and cloudy weather humidity was very high, as a result of which little dehiscence takes place. If after emergence of styles this condition (scarcity of pollens) prevailed for more than twenty-four hours, most of them dry up without being fertilized, resulting in poor seed-setting and consequently in low yield.

DISCUSSION

Studies on floral biology in *bajra* were made in the past by various workers, viz., Ayyanger (1933), Godbole (1927), Burns and Barve (1932), Patwardhan (1927) and Aziz and Bajwa (1956). According to Godbole (1927), protrusion of stigmas on the earhead begins right from the apex downwards, but in our studies the stigmas were found to emerge anywhere from the first upper quarter of the earhead. Others also observed a difference in the total time taken for all the stigmas to emerge. Aziz *et al.* (1956) observed that it required only 24 hours for the completion of this stage while our material took 48 hours. Again, the peak periods from stigmatic protrusion was observed by Aziz *et al.* (1956) to be at 2 a.m., but under our condition the stage was reached at 12 o'clock in the day.

With regard to anther emergence, it was observed by Godbole (1927) to take place nearly at the middle of the earhead, while we noticed the emergence to have started from the apex downwards. The period taken for the completion of the anther emergence throughout the spike ranged between 7 and 9 days, while the peak period was reached on the 4th or 5th day. This observation is, however, not in conformity with that of Ayyanger (1953) who found it to be on the 2nd day. Similarly, the time of maximum anther emergence during one particular day was observed by Ayyanger (1953) to be between 8 p.m. and 10 p.m., by Aziz and Bajwa (1956) between 6 p.m. and 10 p.m.; in our studies it happened to be between 12 and 3 a.m.

Our observations with regard to the time taken for a complete emergence of the ear from the boot happened to be in agreement with that of Aziz and Bajwa (1956). This period varied from 4 to 7 days. Similarly, no break was observed between two flushes of stamens in our material. Burns and Barve (1932) also observed the same.

From the differences of this nature in the mode of anthesis in this crop, leaving apart a few similarities, it is quite evident that either climatic or varietal factors or both may be responsible for it. More investigations are needed in this direction to warrant a final conclusion as to which is a more dominating factor out of these two. Whatever may be the cause of these differences, the real importance lies in the fact that these mainly determine as to what extent the cross-pollination in a particular strain of this crop occurs. Certain characters like a sufficient gap between the first flush of stigmas and the first flush of stamens, complete emergence of the earhead from the boot, so that all the protruding stigmas may be well exposed to foreign pollens, before the onset of the flush of stamens, ensures cent per cent cross-pollination. Strains of this crop having such characters lend themselves easily to successful exploitation of hybrid vigour due to absence of selfing in them.

SUMMARY

The spike took about six days to emerge from the sheath. The maximum emergence of the spike from the sheath took place on fourth and fifth days.

Anthesis always began when the spike was partially in the sheath. It took place in three flushes and lasted for 12 days. The stigma took five to seven hours for coming out of glumes to assume the forked condition and receptivity lasted for 18-21 hours. The styles between 1/10th to 1/4th of the total length of the spike from its tip were the first to come out and two days were required for completing the emergence throughout the spike. The maximum number of styles emerged during day time between 9.00 a.m. and 3.00 p.m. and their peak hour in a particular spike was 12.00 hours on the second day.

Stamens emerged during day and night and they required four to nine days to complete their emergence throughout the panicle. The first stamen emerged two or three days after the style from a point ranging from tip to 1/3rd of the total length of the spike downwards. The maximum number of stamens came out between 0 hours to

2.00 a.m. while minimum number came between 3.00 to 6.00 p.m. Anthers took 15-20 minutes to dehisce and the filaments elongated 3-7 mm. During rains very little or no dehiscence took place.

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INHERITANCE STUDIES IN WHEAT—VII

INHERITANCE OF FIELD REACTION TO STEM RUST AND CERTAIN OTHER CHARACTERS IN CROSSES OF COMMON WHEAT

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Black or stem rust (*Puccinia graminis tritici* (Pers) Eriks & Henn) of wheat is prevalent more or less throughout the country and is responsible along with brown or leaf rusts (*P. rubigovera tritici* (Eriks) Carl.) and yellow or stripe rust (*P. glumaorum* (Schim.) Eriks. and Henn.) for a considerable loss every year, amounting to Rs. 49,000,000 (Vasudeva and Prasada, 1948) during non-epidemic years.

Although systematic work on breeding rust-resistant wheat varieties has been in progress since 1935, the study of genetics of rust resistance has claimed some attention only during recent years in this country. The study of nature of resistance possessed by different rust-resistant varieties becomes all the more imperative with the recent concepts of "resistance breeding".

Discovery of new physiologic races also necessitates tapping of diverse sources of resistance, e.g., in India in the past decade alone as many as eight physiologic races or biotypes of black rust have come to light, viz., 15-C (Gokhale, 1950), 34,117,194 (Prasad and Lele, 1952), 122 (Gokhale and Patil, 1952), 72 (Vasudeva *et al.*, 1953), 21-A (Prasad and Sreekantiah, 1956) and 17 (Vasudeva *et al.*, 1957). In addition to collecting information on rust resistance, information on the different economic characters and their inter-relationships is also needed in wheat breeding work in India.

Investigations carried out to study the mode of inheritance of field resistance to black rust, besides that of certain other characters in some intervarietal crosses of *Triticum aestivum* L., are reported here.

MATERIAL AND METHODS

The material under study consisted of the F_1, F_2 and F_3 progenies of the crosses Pb.C. 518×N.P. 790, Frontiera (E. 957)×Pb.C. 518, Timstein derivative (E. 871) ×N.P. 165, E. 871×N.P. 718, E. 871×Pb.C. 281, and F_1 and F_2 progenies of the cross Pb.C. 273×N.P. 790.

A description of each variety which has entered the crosses under study is given below.

N.P. 165*:* A variety evolved at the Indian Agricultural Research Institute from the cross N.P. 4×Australian Federation. It is an awnless wheat with glabrous white glumes and hard amber grains; susceptible to rusts.

N.P. 718*:* A variety evolved at the I.A.R.I. from the cross N.P. 52×N.P. 165. Fully awned with good amber grains. Susceptible to rusts.

N.P. 790*:* A black-rust-resistant variety evolved at the I.A.R.I. by crossing two susceptible wheats, Thatcher and N.P. 165. It is an awnless wheat with glabrous, brown glumes and red grains. It is highly resistant to all the races of black rust so far found in India, with the exception of race 122.

Pb.C. 281*:* A variety evolved by the Punjab department of Agriculture from the cross Pb.C. 591 × N.P. 4; ears are fully awned and have pubescent white glumes; grains amber, bold and lustrous. Highly susceptible to the rusts.

Pb.C. 518*:* Evolved from the cross Pb. 8.A × Pb. type 9 by the Punjab department of Agriculture. It has short and stiff straw. Ears are compact and fully awned. Grains semi hard; glumes white and pubescent. The variety is highly susceptible to rusts.

Pb.C. 273*:* A recently evolved variety by the Punjab Department of Agriculture from the cross Pb. C. 591 × Pb. C. 209. Although agronomically good, it is susceptible to rusts. It is fully awned, with pubescent white glumes and hard amber grains.

Frontiera (*E.* 957)*:* A brown-rust-resistant variety received from South America. It is fully awned with glabrous white glumes and red grains.

Timstein × 2086 *Sel.* 1495 *A*-1-7-3-1 (*E.* 871)*:* This strain was received from U.S.A. Originally thought to be a derivative from Timstein, it was subsequently found to possess a different source of resistance. It is early-maturing and possesses considerable field resistance to all the three rusts. But for its poor grain quality, the variety has direct introduction value in India, particularly under North Bihar conditions. The variety is fully awned, with glabrous white glumes, and has soft small to medium unshapely grains.

The characters and the crosses in which they were studied have been detailed in Table I.

Table I. Characters studied in the progenies of the crosses involving the various varieties

Characters	Crosses
Black rust	Pb.C. 518 × N.P. 790, Pb.C. 273 × N.P. 790.
Grass clump habit	Pb.C. 273 × N.P. 790, Pb.C. 518 × N.P. 790, E. 871 × N.P. 718, E. 871 × Pb.C. 281, E. 957 × Pb.C. 518.
Necrotic leaf spot	Pb.C. 273 × N.P. 790.
Anothocyanin pigmentation of the rachis	Pb.C. 273 × N.P. 790, Pb.C. 518 × N.P. 790.
Awning	Pb.C. 518 × N.P. 790, E. 871 × N.P. 165.
Glume beak	Pb.C. 518 × N.P. 790, E. 871 × N.P. 165.
Glume pubescence	Pb.C. 273 × N.P. 790, Pb.C. 518 × N.P. 790, E. 871 × Pb.C. 281, E. 957 × Pb.C. 518.
Glume colour	Pb.C. 273 × N.P. 790, Pb.C. 518 × N.P. 790.
Glume shoulder	Pb.C. 518 × N.P. 790, Pb.C. 273 × N.P. 790.
Grain colour	Pb.C. 518 × N.P. 790, E. 957 × Pb.C. 518.

The material was sown in the first week of November, 1958, in blocks of the size 48 ft. × 6 ft. A spacing of 5 ft. between the blocks, 1 ft. between the rows and 4 in. between the plants was maintained. All the four borders and the 17th and 33rd rows of each block were sown with infector varieties consisting of Malvi local, Kathia, Motia (all belonging to *T. durum*), Agra local (*T. aestivum*) and *T. vavilovi.*

Races 15, 15C, 21, 21A, 24, 34, 40, 42, 42B, 75, 117 and 194 of black rust were released in water suspension. In addition, to ensure greater infection, the rust inoculum after mixing with talc powder was also dusted, as suggested by Cherwick (1946).

Black rust observations were recorded on the basis of both type of reaction and degree of intensity of infection. The types of rust reactions, viz. resistant, semi-resistant, susceptible and mesothetic were recorded in accordance with the system followed by other workers in the field. For degree of intensity, the scale suggested by Pal, Sikka and Rao (1956) was used.

For studying the inheritance of grass clump habit, all the different types of grass clumps (from small sterile ones to partially fertile) were taken together and compared with normal ones.

For necrotic leaf spots, only two classes were maintained, viz., normal plants and plants showing necrotic spots.

Anthocyanin pigmentation of the rachis in between the spikelets was studied. Only two classes were recognised, viz., plants with pigmented rachis and plants with non-pigmented rachis.

For recording awn character, five awn classes as suggested by Pal *et al.* (1941) were adopted; however, only the fully awned class was kept separate and the remaining four classes were grouped together.

In recording glume beak, the following four classes were taken into account:

(a) Acuminate: beak pointed and drawn out (about 5 mm.)

(b) Acute 1: beak pointed, short and slightly drawn out (2-3 mm.)

(c) Acute 2: beak pointed, but not drawn out

(d) Obtuse: beak short and blunt

For observations on glume pubescence three classes were maintained, viz., thickly pubescent, sparsely pubescent and glabrous. However, for the purpose of genetic interpretation, both the pubescent classes were combined and compared against the smooth or glabrous class.

As regards glume colour only two broad classes were recognized, viz., brown and white.

For observations on glume shoulder, three classes were maintained, viz., square, wanting and squarish (intermediate). However, for the genetic analysis square and squarish classes were grouped together. Observations were confined to the middle spikelets.

As regards grain colour, classification was broadly done into two main classes, viz., red and amber (white).

OBSERVATIONS

(1) *Inheritance of field reaction to black rust:* The varieties Pb.C. 518 and Pb.C. 273 showed high susceptibility, while N.P. 790 was completely free from the black rust.

All the F_1 plants were susceptible, indicating thereby the dominance of susceptibility. The reaction of the parents, F_1 and F_2 generations are presented in Table II.

TABLE II. FIELD REACTION TO BLACK RUST OF THE PARENTS, F_1 AND F_2 GENERATIONS OF THE CROSSES PB.C. 518×N.P. 790 AND PB.C. 273×N.P. 790

Material	No. of plants		Total No. of plants	X^2	P. value
	Resistant (R)	Susceptible (S)			
Pb.C. 518 × N.P. 790					
Pb.C. 518	..	24	24		
N.P. 790	36	..	36		
F_1	..	12	12		
F_2 (observed)	23	451	474		
F_2 (expected 61S:3R)	22·2187	451·7812	..	0·0286	0·90–80
Pb.C. 273 × N.P. 790					
Pb.C. 273	35	..	35		
N.P. 790	..	26	26		
F_1	..	5	5		
F_2 (Observed)	21	475	496		
F_2 (expected) 61S:3R	23·25	472·75	..	0·2284	0·70-50

The F_2 data indicate that field reaction to black rust in these crosses is governed by three factor pairs. These F_2 findings were confirmed in the F_3 generation of the cross Pb.C. 518×N.P. 790, and the results are presented in Table III.

TABLE III. FIELD REACTION TO BLACK RUST IN THE F_3 FAMILIES OF THE CROSS PB.C. 518×N.P. 790

Material	No. of families		Homozygous resistant	Total	X^2	P. value
	Homozygous susceptible (S)	Heterozygous (H)	(R)			
F_3 (Observed)	59	28	..	87		
F_3 (expected 37S: 26H:1R)	50·2978	35·3444	1·3594		4·192	0·20–10

Out of 87 families, 59 bred true for susceptibility and none for resistance. Of the 28 segregating families, two segregated in the ratio of 61S:3R, seven in the ratio of

15S:1R, 16 in the ratio of 13S:3R and 3S:1R and three in the ratio of 3R:1S. The number of families homozygous for susceptibility was more than expected. The homozygous resistant class was altogether missing, apparently due to the small number of families under study.

(ii) *Inheritance of grass clump habit:* Grass clumps (dwarf wheat plants looking like clumps or tufts of grass) were observed in the segregating generations of the crosses E. 871 × N.P. 718, E. 871 × Pb.C. 281, E. 957 × Pb.C. 518, Pb.C. 273 × N.P. 790 and Pb.C. 518 × N.P. 790. Most of the grass clumps were small and died after a certain stage of development. Some of them reached the heading stage, but the grain setting was very poor, rather non-existent. All the parents and F_1 plants were of normal habit, indicating the dominance of normal habit. In the F_2 of all the crosses studied, segregation into the ratio of 63 normal: 1 dwarf was obtained, indicating the operation of three factors. The F_2 results are presented in Table IV.

TABLE IV. MODE OF SEGREGATION FOR GRASS CLUMPS IN THE F_2 GENERATION OF THE CROSSES E. 871 × N.P. 718, E. 871 × PB.C. 281, E. 957 × PB.C. 518, PB.C. 273 × N.P. 790 AND PB. C. 518 × N.P. 790

Material	No. of normal plants (N)	No. of grass clumps (GC)	Total	X^2	P. value
(E. 871 × N.P. 718) F_2 (obs.)	468	6	474	0·2712	0·70–·50
,, (Exp. 63N:1GC	466·5969	7·4063			
(E. 871 × Pb.C. 281) F_2 (obs.)	350	4	354		
,, (Exp. 63N:1GC)	348·4656	5·5312		0·4306	0·70–·50
(E. 957 × Pb.C.-518) F_2 (obs.)	540	2	542		
,, (Exp. 63N:IGC)	533·5313	8·4688		3·5656	0·10–·05
(Pb.C. 273 × N.P. 790) F_2 (obs.)	494	11	505		
,, (Exp. 63N:IGC)	497·1094	7·8906		1·2447	0·30–·20
(Pb.C. 518 × N.P. 790) (obs.)	493	10	503		
,, (Exp. 63N:IGC)	495·1406	7·8593		0·5293	0·50–·30

The F_2 findings were confirmed by the mode of segregation in the F_3 families of the crosses E. 871 × N.P. 718 and E. 871 × Pb.C. 281 (Table V).

TABLE V. MODE OF SEGREGATION FOR GRASS CLUMPS IN THE F_3 FAMILIES OF THE CROSSES E. 871 × N.P. 718 AND E. 871 × PB.C. 281

Material	No. of families		Total	X^2	P. value
	Homozygous normal (N)	Heterozygous (H)			
(E. 871 × N.P. 718) F_3 (obs.)	51	18	69		
,, (Exp. 37N:26H)	40·5224	28·4752	..	5·3696	0·05–·02
(E. 871 × Pb.C. 281) (F_3 obs.)	47	17	64		
,, (Exp. 37N:26H)	37·5883	26·4134	..	5·7114	0·02–·01

The F_3 results show a very poor fit, although the trend followed rather closely the F_2 findings. In the remaining two crosses, viz., E. 957 × Pb.C. 518 and Pb.C. 518 × N.P. 790, the number of segregating families was far too less and no attempt was made to analyse the data. The number of segregating families was 13 (out of 85 families) in the cross E. 957 × Pb.C. 518 and 11 (out of 87 families) in the cross Pb.C. 518 × N.P. 790. The dearth of segregating families in all the four crosses is apparently due to smaller number of plants per family for a three-factor segregation. No pure breeding family for grass clumps was obtained. Since all the grass clumps die out before producing seed, no true breeding F_3 family is expected either.

(iii) *Inheritance of necrotic leaf spot:* The inheritance of necrotic leaf spot was studied in the cross Pb.C. 273 × N.P. 790. The variety Pb.C. 273 was found to develop non-parasitic necrotic leaf spots on the full grown leaves, while N.P. 790 was completely free from such spots. The F_1 was normal. There was clear segregation in the F_2 generation for plants with and without necrotic leaf spots. The data on the parents, F_1 and F_2 are presented in Table VI.

TABLE VI. NECROTIC LEAF SPOTS ON THE PARENTS F_1 AND F_2 OF THE CROSS PB.C. 273 × N.P. 790

Material	Number of plants		Total	X^2	P. value
	With normal leaves (N)	With necrotic leaves (Nec.)			
Pb.C. 273	..	35	35		
N.P. 790	26	..	26		
F_1	5	..	5		
F_2 (observed)	351	122	473		
F_2 (Exp. 3N:1Nec.)	354·75	118·25	..	0·1585	0·70–0·50

In the F_2 there was considerable variation as regards number and size of necrotic spots from leaf to leaf and plant to plant. The young leaves were free from such spots, but with maturity of the leaves the necrotic spots appeared. The F_2 results show a segregation ratio of 3N:1Nec., indicating thereby the operation of a single factor pair controlling necrotic leaf spots.

(iv) *Inheritance of anthocyanin pigmentation of the rachis:* This was studied in the crosses Pb.C. 273 × N.P. 790 and Pb.C. 518 × N.P. 790. The variety N.P. 790 was found to develop anthocyanin pigmentation on the rachis in between the spikelets, while the rachis in Pb.C. 273 and Pb.C. 518 was throughout light green. All the F_1 plants remained green. The data on development of pigment on the rachis in the parents F_1 and F_2 are presented in Table VII.

Table VII. Anthocyanin pigmentation on the rachis of the parents F_1, and F_2 of the crosses Pb.C. 518×N.P. 790 and Pb.C. 273×N.P. 790

Material	No. of plants with		Total	X^2	P. value
	Non-pigmented rachis (G)	Pigmented rachis (P)			
Pb.C. 518 × N.P. 790					
Pb.C. 518	24	..	24		
N.P. 790	..	36	36		
F_1	12	..	12		
F_2 (Observed)	340	87	427		
F_2 (Exp. 13G:3P)	346·9375	80·0625	..	0·7398	0·50–0·30
Pb.C. 273 × N.P. 790					
Pb.C. 273	35	..	35		
N.P. 790	..	26	26		
F_1	5	..	5		
F_2 (Observed)	344	78	422	0·0197	0·90–0·80
F_2 (Exp. 13G:3P)	342·875	79·125			

F_2 data indicate that anthocyanin pigmentation is governed by two-factor pairs in these crosses. The F_2 findings were confirmed by the mode of segregation in the F_3 families of the cross Pb.C. 518×N.P. 790 (Table VIII).

Table VIII.

Material	Homozygous non-pigmented (G)	Heterozygous (H.)		Homozygous, pigmented (P)	Total	X^2	P. value
		13G:3P & 3G:1P	3P:1G				
F_3	32	41	8	6	87		
F_3 (Exp. 7G:8H:1P)	38·0625	32·625	10·875	5·4375		4·4575	0·30–0·20

The F_3 results tend to confirm the F_2 findings. Thus, there appears to be an inhibitory factor which suppressed the expression of the factor controlling the anthocyanin pigmentation of N.P. 790.

(v) *Inheritance of awning:* This character was studied in the crosses E. 871× N.P. 165 and Pb.C. 518×N.P. 790. The varieties E. 871 and Pb.C. 518 were the fully awned parents, while N.P. 165 and N.P. 790 comprised the awnless parents. The F_1 plants were long tipped in both the crosses, thus indicating the partial

dominance of awnless condition. In the F_2 generation all the awn classes, viz., awnless, short tipped, long tipped, half awned and fully awned, were obtained. However, due to partial dominance of awnlessness over awnedness, the awnless and tipped class, alongwith the half awned class, was grouped (AL) and compared against the recessive class, viz., fully awned (A). The F_2 results are presented in Table IX.

TABLE IX. SEGREGATION FOR AWN TYPES IN THE F_2 GENERATION OF THE CROSSES E. 871 × N.P. 165 and Pb.C. 518 × N.P. 790

Material	No. of plants		Total	X^2	P. value
	Awnless to half awned (AL)	Fully awned (A)			
(E. 871 × N.P. 165) F_2 (obs.)	471	36	507		
,, (Exp. 15AL:1A)	475·3125	31·6875	..	0·0615	0·90–0·80
(Pb.C. 518 × N.P. 790) F (obs.)	448	19	467		
,, 15AL:1A)	437·8125	29·1875	..	3·7928	0·10–0·05

The F_2 results show that awn character in both the crosses is controlled by two factors giving a segregation ratio of 15AL (composite): 1A. However, in the cross Pb.C. 518 × N.P. 790, the number of fully awned plants was much less than expected, and the P. value was also low. Still the data can be interpreted as showing a tendency towards the expected ratio of 15AL:1A. The F_2 results were confirmed by a study of mode of segregation of this character in the F_3 families (Table X).

TABLE X. MODE OF SEGREGATION FOR AWN CHARACTER IN THE F_3 FAMILIES OF THE CROSSES E. 871 × N.P. 165 AND PB.C. 518 × N.P. 790

Material	No. of families			Total	X^2	P. value
	Homozygous fully awned (A)	Heterozygous (H)	Awnless & tipped			
(E. 871 × N.P. 165) F_3 (obs.)	5	34	24	63		
,, (Exp. 1A:8H:7T)	3·9375	31·5	27·5625	..	0·9625	0·70–0·50
(Pb.C. 518 × N.P. 790) F_3 (obs.)	2	38	47	87		
,, (Exp. 1A:8H:7T)	5·4375	43·5	38·0625	..	4·9671	0·10–0·05

It would be observed that while a good fit for the expected ratio of 1A:8H:7AL was observed in the cross E. 871 × N. P. 165, a very poor fit was obtained in the cross E. 871 × N.P. 790. The number of homozygous awned and heterozygous families was less than expected in this cross and reflected the trend observed in the F_2, where also the number of fully awned plants was less than

expected. Out of 34 segregating families in the cross E. 871 × N.P. 165, 14 families segregated in the ratio of 3AL:1A and 20 in the ratio of 15AL:1A, while in the cross Pb.C. 518 × N.P. 790, out of 38 segregating families, 21 segregated in the ratio of 3AL:1A and 17 in the ratio of 15AL:1A. These figures roughly conform to the expected ratio of 1 (15:1):1 (3:1) and tend to show that awn character in these crosses is controlled by two factors.

(vi) *Inheritance of glume beak shape:* The inheritance of glume beak shape was studied in the crosses E. 871 × N.P. 165 and Pb.C. 518 × N.P. 790. The varieties E. 871 and Pb.C. 518 had acuminate beak shape, while both N.P. 165 and N.P. 790 had obtuse beak shape. In the F_1 beak shape was of the type acute 2 in both the crosses, showing thereby the partial dominance of obtuse beak shape. In the F_2 generation, all the four beak types, viz., acuminate, acute 1, acute 2 and obtuse were observed. However, due to partial dominance of obtuse shape over acuminate, the obtuse and both the acute types were taken together as one class (O) and compared against the recessive class, viz., acuminate (A). The F_2 observations have been presented in Table XI.

Table XI. Mode of segregation for glume beak shape in the crosses E. 871 × N.P. 165 and Pb.C. 518 × N.P. 790

Material	No. of plants with		Total	χ^2	P. value
	Obtuse beak shape (O)	Acuminate beak shape (A)			
(E. 871 × N.P. 165) F_2 (obs.)	471	36	507		
,, (Exp. 150:1A)	475·3125	31·6875	..	0·0615	0·90–0·80
(Pb.C. 518 × N.P. 790) F_2 (obs.)	448	19	467		
,, (Exp. 150:1A)	437·8125	29·1875	..	3·7928	0·10–0·05

In the case of the cross E. 871 × N.P. 165 a good fit was obtained for the segregation ratio of 15 O:1A while in the cross Pb.C. 518 × N.P. 790, a very poor fit was observed. Nevertheless, the results show a tendency towards 150:1A ratio. These results indicate that glume beak shape is controlled by two factor pairs in both the crosses.

(vii) *Inheritance of glume pubescence:* Inheritance of glume pubescence was studied in the crosses E. 871 × Pb.C. 281, E. 957 × Pb.C. 518, Pb.C. 518 × N.P. 790 and Pb.C. 273 × N.P. 790. The varieties Pb.C. 281, Pb.C. 518 and Pb.C. 273 possess pubescent glumes, while E. 871, E. 957 and N.P. 790 have glabrous glumes.

In the F_1, pubescent condition of the glume was found dominant. In the F_2, segregation was observed in the ratio of 3 pubescent: 1 glabrous in all the four crosses (Table XII), showing thereby the monofactorial dominance of pubescent over glabrous condition.

TABLE XII. MODE OF SEGREGATION FOR GLUME PUBESCENCE IN THE F_2 GENERATION OF THE CROSSES E. 871 × Pb.C. 281, E. 957 × Pb.C. 518, Pb.C. 273 × N.P. 790 and Pb.C. 518 × N.P. 790

Material	No. of plants with Pubescent glumes (P)	Glabrous glumes (G)	Total	X^2	P. value
(E. 871 × Pb.C. 281 F_2 (obs.)	300	107	407		
,, (Exp. 3P:1G)	305·25	101·75	..	0·3415	0·70–0·50
(E. 957 × Pb.C. 518) F_2 (obs.)	379	127	506		
,, (Exp. 3P:1G)	379·5	126·5	..	0·0027	0·98–0·95
(Pb.C. 518 × N.P. 790) F_2 (obs.)	334	107	441		
,, (Exp. 3P:1G)	330·75	110·25	..	0·1277	0·80–0·70
(Pb.C. 273 × N.P. 790) F_2 (obs.)	330	111	441		
,, (Exp. 3P:1G)	330·75	110·25	..	0·0068	0·95–0·90

Further support for this indication came from the study of the mode of segregation in the F_3 families (Table XIII).

TABLE XIII.

Material	No. of families Homozygous pubescent (P)	Heterozygous (H)	Homozygous glabrous (G)	Total	X^2 ..	P. value
(E. 871 × Pb.C. 281) F_3 (obs.)	9	28	13	50		
,, (Exp. 1P:2H:1G)	12·5	25	12·5	..	1·36	0·98–0·95
(E. 957 × Pb.C. 518) F_3 (obs.)	19	49	17	85		
,, (Exp. 1P:2H:1G)	21·5	42·5	21·25	..	2·0588	0·50–0·30
(Pb.C. 518 × N.P. 790) F_3 (obs.)	17	51	19	87		
,, (Exp. 1P:2H:1G)	21·75	43·5	21·75	..	2·6722	0·30–0·20

The F_3 data conform to the expected ratio 1P:2H:1G, to confirm the F_2 findings.

Further, in the segregating generation of all the crosses, transgressive segregation for pubescence (plants more pubescent than pubescent parents) was observed, indicating perhaps the operation of modifying factor or factors.

(viii) *Inheritance of glume colour:* Inheritance of glume colour was studied in the crosses of brown glumed variety N.P. 790 with white glumed varieties Pb.C. 273 and Pb.C. 518. In the F_1, dominance of brown colour over white was observed. In the

F_2, segregation was found to follow a monogenic pattern, giving a ratio of 3 brown: 1 white (Table XIV).

TABLE XIV. MODE OF SEGREGATION FOR GLUME IN THE F_2 GENERATION OF THE CROSSES PB.C. 518 × N.P. 790 AND PB.C. 273 × N.P. 790

Material	No. of plants with		Total	X^2	P. value
	Brown glumes (Br)	White glumes (W)			
(Pb.C. 518 × N.P. 790) F_2 (obs.)	354	124	478		
,, (Exp. 3Br:1W)	358·5	119·5	..	0·226	0·70–0·50
(Pb.C. 273 × N.P. 790) F_2 (obs.)	366	116	482	0·224	0·70–0·50
,, (Exp. 3Br:1W)	361·5	120·5			

The F_2 results were confirmed by the observations on the mode of segregation in the F_3 families of the cross Pb.C. 518 × N.P. 790 (Table XV) where the expected segregation ratio of 1Br:2H:1W was observed.

TABLE XV. MODE OF SEGREGATION FOR GLUME COLOUR IN THE F_3 FAMILIES OF THE CROSS PB.C. 518 × N.P. 790

Material	No. of families			Total	X^2	P. value
	Homozy. brown (Br)	Heterozy. (H)	Homozy. white (W)			
F_3 (Observed)	17	47	23	87		
F_3 (Expected 1Br: 2H:1W)	21·75	43·5	21·75	..	1·391	0·70–0·50

(ix) *Inheritance of glume shoulder:* This character was studied in the crosses Pb.C. 273 × N.P. 790 and Pb.C. 518 × N.P. 790. The observations were recorded on the middle spikelets. The variety N.P. 790 had square glume shoulders, while in both Pb.C. 273 and Pb.C. 518 shoulder was wanting. Although the F_1 plants had intermediate shoulders, they were tending more towards square side in both the crosses. The F_2 data (Table XVI) indicated a monofactorial basis of inheritance.

(x) *Inheritance of grain colour:* Inheritance of grain colour was studied in the crosses Pb.C. 518 × N.P. 790 and E. 957 × Pb.C. 518. The varieties E. 957 and N.P. 790 have red grains, while Pb.C. 518 is amber-grained. In the F_1, of both the crosses red colour of the grains was found dominant. In the F_2, a ratio of 3 red:1 amber in the cross Pb.C. 518 × N.P. 790, of 63 amber: 1 red in the cross E. 957 × Pb.C. 518 was observed, indicating thereby the operation of 1 factor in case of the first and 3 factors in case of the last in controlling the grain colour. Data on grain colour of the parents, F_1, and F_2 generations of these crosses are presented in Table XVII.

TABLE XVI. SHAPE OF GLUME SHOULDERS IN THE F_2 GENERATION OF THE CROSSES PB.C. 518 × N.P. 790 AND PB.C. 273 × N.P. 790

Material	No. of plants with Square & interm. shoulders (S)	Wanting shoulders (W)	Total	X^2	P. value
(Pb.C. 518 × N.P. 790) F_2 (obs.)	353	117	470		
,, (Exp. 3S:1W)	352·5	117·5	..	0·0028	0·98–0·95
(Pb.C. 273 × N.P. 790) F_2 (obs.)	344	117	461		
,, (Exp. 3S:1W)	345·75	115·25	..	0·0356	0·90–0·80

TABLE XVII. GRAIN COLOUR OF THE PARENTS, F_1 AND F_2 OF THE CROSSES PB.C. 518 × N.P. 790 AND E. 957 × PB.C. 518.

Material	No. of plants with Red grains (R)	Amber grains (A)	Total	X^2	P. value
Pb.C. 518 × N.P. 790					
Pb.C. 518	..	24	24		
N.P. 790	36	..	36		
F_1	12	..	12		
F_2 (Observed)	351	116	467		
F_2 (Exp. 3R:1A)	350·25	116·75	..	0·0065	0·95–0·90
E. 957 × *Pb.C.* 518					
E. 957	33	..	33		
Pb.C. 518	..	26	26		
F_1	12	..	12		
F_2 (Observed)	467	10	477		
F_2 (Exp. 63R:1A)	469·5469	7·4531	..	0·8843	0·50–0·30

DISCUSSION

(i) *Inheritance of field reaction to black rust:* The mode of inheritance of field reaction to black rust was studied in the crosses Pb.C. 518(S) × N.P. 790(R) and Pb.C. 273(S) × N.P. 790(R). The variety N.P. 790 evolved from the cross N.P. 165 × Thatcher is resistant to all the races of black rust met with in India, except race 122, and is a very

important source of resistance. The two susceptible varieties Pb.C. 518 and Pb.C. 273 are agronomically good. In both the crosses susceptibility was dominant and in the F_2 a trihybrid ratio of 61S:3R was obtained. These F_2 observations were confirmed by a study of the F_3 generation in the cross Pb.C. 518 × N.P. 790.

Field reaction to black rust controlled by 3 factors has also been reported by Cortazer (1944), Shebeski and Wu (1952), Das (1954), Sikka and Rao (1958), etc. However, the segregation ratio of 61S:3R has been reported only by Sikka and Rao (1958).

The trihybrid ratio may be taken to indicate that the two recessive genes and one dominant gene which interact to give the ratio of 61S:3R, have a cumulative effect, each gene conditioning resistance to different set of races. Alternatively, the results can be interpreted by assuming that the field resistance is conditioned by the complementary action of two recessive genes and one dominant gene. On the consideration of the parentage of N.P. 790, viz., N.P. 165(S) × Thatcher(S), the latter hypothesis seems to be more correct. The resistance of Thatcher has been reported to be conditioned by two complementary recessive genes by Koo and Ausemus (1951). Swenson *et al.* (1947) and Macindoe (1948) also found the resistance of Thatcher to be governed by at least two recessive genes. Pan (1940) noted the resistance of Minn. Double cross 11-21-80, a sister selection of Thatcher, to depend on two complementary recessive genes. The results obtained by these workers seem to indicate that Thatcher type of resistance is conditioned by two recessive and most probably complementary factors. Sikka and Rao (1958) reported the resistance of N.P. 790 to be conditioned by two recessive and one dominant genes in the crosses N.P. 718(S) × N.P. 790(R) Pb.C. 281(S) × N.P. 790(R) and Pb.C. 591 × N.P. 790(R). These workers further mentioned that both Thatcher and N.P. 165 which enter the parentage of N.P. 790 are susceptible to black rust under Indian conditions. In view of these findings, they assumed that N.P. 790 might have inherited the two complementary recessive genes present in it from Thatcher alongwith one more gene from N.P. 165, the combined action of all of which gave field resistance to N.P. 790. The results of the present studies confirm these earlier findings of Sikka and Rao (1958).

(ii) *Inheritance of grass clump habit:* Grass clumps or dwarfs were found in the segregating generations of the crosses E. 871 × N.P. 718, E. 871 × Pb.C. 281, E. 957 × Pb.C. 518, Pb.C. 273 × N.P. 790 and Pb.C. 518 × N.P. 790.

In all these crosses, grass clumps were observed to represent the triple recessive condition. Even one gene in dominant condition resulted in normal wheat plant.

Neethling (1917) reported grass clump habit to be conditioned by a single recessive gene. Waterhouse (1930) noted a ratio of 15 normal:1 dwarf, in some of the crosses studied by him. However, most of the investigators have found the grass clumps to be conditioned by basically dominant factor or factors. Thus, grass clumps in the segregation have been explained on the basis of a dominant dwarf factor along with an inhibitor (Hayes and Aamodt, 1923; Clark, and Hooker, 1926; Goulden, 1926; Stephens, 1927; Stewart and Tingey, 1928; Clark and Quisenberry, 1929; Churchward, 1930; Waterhouse, 1930; Stewart and Bischoff, 1931; Tingey, 1931; Everson *et al.*, 1957); on the basis of a dominant dwarf factor, its inhibitor and inhibitor of the inhibitor (Thompson, 1928; Florell and Martin, 1936); on the basis of a dominant

dwarf factor, its inhibitor and inhibitor of the inhibitor composed of two complementary factors (McMillan, 1937); on the basis of two dominant complementary factors (Kostyuchenko, 1936; Hsu, Sunderman and Ausemus, 1955; Hermsen, 1957); on the basis of two dominant complementary factors along with the epistatic factor for normal habit (Florell, 1931); on the basis of three dominant duplicate complementary factors and one inhibitor (Pao *et al.*, 1941), etc.

The results obtained in the present studies, where grass clump habit was found to be conditioned by recessive factors, seem to be contrary to that obtained by most of the investigators. However, it is possible that a different system also exists, as evidenced by the works of Neethling (1917) and Waterhouse (1930), besides the present work.

(iii) *Inheritance of necrotic leaf spot:* The inheritance of necrotic leaf spot was studied in the cross Pb.C. 273 (nec.) ×N.P. 790 (normal). The results indicated this character to be inherited on a simple monofactorial basis, necrotic condition behaving as recessive.

Since the variety Pb.C. 273 develops the necrotic spots, the recessive factor for necrosis must be located in that variety and its dominant allele in N.P. 790. Necrotic leaf spot inherited on a monofactorial basis and representing the recessive condition, has also been reported by Straib (1935), and by Sikka and Jain (1959) in the cross N.P. 718 (normal) × (Supremo × Mentana) (necrotic).

(iv) *Inheritance of anthocyanin pigmentation of the rachis:* The inheritance of anthocyanin pigmentation was studied in the crosses Pb.C. 518 (green) ×N.P. 790 (pigmented) and Pb.C. 273 (green) ×N.P. 790 (pigmented). Although in the F_1 generation, pigmentation was found to be recessive, segregations obtained in the F_2 and F_3 conformed to 13 (non-pigmented) 3 (pigmented) ratio, indicating thereby the operation of basically dominant factor for anthocyanin pigmentation and its inhibitor.

Since N.P. 790 has pigmented rachis, it is logical to assume that the pigmentation factor is located in that variety, while its inhibitor was carried by Pb.C. 273 and Pb.C. 518.

Although no literature was available as regards anthocyanin pigmentation of the rachis, monogenic control of anthocyanin pigmentation was reported by Kajanus (1918) for auricle colour, by Jenkin (1925) for straw colour and by Kadam and Kulkarni (1937) for ligule colour. Duplicate factors have been reported by Goulden, Neatby and Welsh (1928) and Quisenberry (1931) for red coleoptile colour.

(v) *Inheritance of awning:* Inheritance of awn character was studied in two crosses, viz., E. 871(A) ×N.P. 165(AL) and Pb.C. 518(A) ×N.P. 790(AL). The results indicated two factor difference with partial dominance of awnlessness over awnedness, in both the crosses.

It can be inferred from the results obtained that the varieties N.P. 165 and N.P. 790 carry two dominant awn inhibitors, while E. 871 and Pb.C. 518 carry their recessive alleles.

In the cross Pb.C. 518 ×N.P. 790, the number of awned plants was found to be less than expected in the F_2 and F_3 generations. It was felt that there might be factor or factors, besides the awn inhibiting genes, which interfere with the expression of

awned condition. It is possible that such factors might be the awn promoting "a" factors postulated by Heyne and Livers (1953). It may be mentioned that the allele 'A' is partially dominant over the awn promoting "a" alleles, while the awn inhibitory genes are partially epistatic over "a" (Heyne and Livers, 1953). In the inheritance studies of awning by the conventional genetic methods, usually the role of awn promoters is not given due recognition, presumably due to their minor individual effect. However, it is possible that some of the awned varieties might possess the minimum prerequisite for awned condition, and any reduction from that minimum, results in tipped or awnless condition. It may be noted that in this cross the number of awnless plants in the F_2 and the number of homozygous awnless families in the F_3 were more than expected. Deficiency of awned plants in the segregating generations was also observed by Kajanus (1923) and Watkins (1928). However, Kajanus explained his results on the basis of differential winter killing, while the latter did not offer any explanation.

Bifactorial control of awning has been reported by many workers (Biffen, 1905; Gaines and Singleton, 1926; Goulden *et al.*, 1928; Clark *et al.*, 1928; Stewart and Heywood, 1929; Stewart and Price, 1929; Waterhouse 1930; Stewart and Judd, 1931; Clark *et al.*, 1933; Tai, 1934; Ausemus, 1934; Churchward, 1938; Watkins and Ellerton, 1940; Pal *et al.*, 1958; Sikka and Rao, 1957; ElKhishen and Salem, 1958; Ghosh *et al.*, 1958; etc.). In almost all the cases, crosses between awnless and fully awned gave 15 awnless and tipped: 1 awned. Watkins and Ellerton (1940) postulated 5 major genes, viz., B_1, B_2 b_1^a, b_2^a, (or A) and Hd to explain different awn types while Saulescu (1933) and Khan (1956) explained their findings on the basis of three and four factors, respectively.

However, in recent years, with the aid of monosomic analyses (Sears, 1944; O'Mara, 1948; Unrau, 1950; and Heyne and Livers, 1953; Wiggin, 1955; Sikka *et al.*, 1956, etc.) as many as ten chromosomes have been shown to be directly associated with awn expression. Of these, four chromosomes, viz., VIII, IX, X and XVII carry awn inhibitors, while II, III, XII, XVI, XX and XXI have been shown to carry awn promoters. And as such the expression of awning is quite complicated.

(vi) *Inheritance of glume beak shape:* The results obtained in the crosses Pb.C. 518 (acuminate) × N.P. 790 (obtuse) and E. 871 (acuminate) × N.P. 165 (obtuse), with regard to the inheritance of glume beak shape show this character to the controlled by two factor pairs. Obtuse beak was found to be partially dominant over acuminate beak. On the basis of the results obtained, it can be said that the varieties N.P. 790 and N.P. 165 carry the dominant factors conditioning obtuse beak shape, while E. 871 and Pb.C. 518 carry their recessive alleles.

These results are at variance with the findings of Tai (1934) and Shen, Tai and Chang (1938) who found obtuse glume beak shape to be monogenically dominant over acute beak shape. However, in the present studies obtuse, acute 1 and acuminate were observed to be linked with awnless, half awned as well as tipped, and fully awned conditions, respectively. On the basis of this observation and considering the fact that awning is controlled by two factors, it is difficult to visualise a monogenic control of this character, as reported by these workers.

(vii) *Inheritance of glume pubescence:* Inheritance of glume pubescence was studied in the crosses E. 871 (glabrous) × Pb.C. 281 (hairy), E. 957 (G) × Pb.C. 518(H), Pb.C. 273(H) × N.P. 790 (G) and Pb.C. 518(H) N.P. 790(G). In all these crosses, a single dominant gene was found to govern the pubescent character of the glume.

These findings gain support from the results reported by a host of workers who found pubescent condition to be monogenically dominant over the glabrous condition (Hayes and Boss, 1899; Spillman, 1902; Watkins and Cory, 1932; Torrie, 1936; Kadam, 1936; Chevertte, 1942; Atkins, 1948; Das, 1954; Khan, 1956; Pal *et al.*, 1956; Sikka and Rao, 1957; Ghosh *et al.*, 1958). Howard and Howard (1912, 1915), however, reported two independently inherited factors for pubescence, while Vacenko (1934) postulated multiple alleles for different hair lengths.

In the segregating generations, it was observed that some of the segregates were more hairy than the hairy parent. It is felt that this might be due to the operation of some minor or modifying factors. Sikka and Rao (1957) also indicated such possibility.

(viii) *Inheritance of glume colour:* In both the crosses studied, viz., Pb.C. 273(W) × N.P. 790(Br) and Pb.C. 518(W) × N.P. 790(Br), the brown glume colour was found to be monofactorially dominant over white glume colour.

Most of the workers have reported the same mode of inheritance (Biffen, 1905; Howard and Howard, 1912; Clark, 1924; Clark and Hooker, 1926; Stewart, 1928; Stewart and Tingey, 1928; Florell, 1931; Stewart, 1931; Tingey and Tolman, 1934; Kadam, 1936; Chevertte, 1942; Pal *et al.*, 1956; Sikka and Rao, 1957, etc.). However, Tai (1939) and Torrie (1936) reported brown glume colour to be controlled by two factors, while Sen and Joshi (1955) and Slavko Borojevic (1956) found two dominant complementary factors conditioning brown glume colour.

(ix) *Inheritance of glume shoulder:* Inheritance of this character was studied in the crosses Pb.C. 273 (wanting) × N.P. 790 (square) and Pb.C. 518 (wanting) × N.P. 790 (square). The square glume shoulder of N.P. 790 was found to be incompletely dominant over the wanting shoulders of Pb.C. 273 and Pb.C. 518, and segregated in the F_2 generation on a single gene basis.

As compared to the monofactorial nature of this character in the present studies, Tai (1934) found the narrow glume shoulder to be conditioned by the complementary action of two dominant factors.

(x) *Inheritance of grain colour:* Inheritance of grain colour was studied in two crosses, viz., E. 957 (red) × Pb.C. 518 (amber) and Pb.C. 518(A) × N.P. 790(R). Since varying results were obtained in these crosses, they have been discussed separately.

1. *The Cross E.* 957 × *Pb.C.* 518*:* Red colour of E. 957 (Frontiera) was found to be dominant and conditioned by three duplicate factors. Similar results have been reported for this variety by Sikka and Rao (1957) and Ghosh *et al.* (1958). All these studies thus reveal that Frontiera carried three pairs of dominant duplicate factors for red grain colour.

Red grain colour conditioned by three duplicate factors has also been reported by Nilsson-Ehle (1911), Gaines (1917), Stewart (1928), Waterhouse (1930) Stewart and Woodward (1931), Tingey and Tolman (1934), Torrie (1936), Nieves (1937, 1938, 1939), Churchward (1938), Worzella (1942), etc.

It has been generally assumed that each factor for red grain colour has a cumulative effect. However, in the present studies no such indication was obtained. The intensity of the colour varied with the texture of the grain, the hard texture giving a darker shade and the soft types a lighter shade. The variety E. 957 itself has got light red grains, though it carries three dominant factors for red colour.

2. *The Cross Pb.C.* 518×*N.P.* 790*:* The results obtained in this cross showed that N.P. 790 carries a single dominant factor for red colour of grains. Similar results have also been reported by Sikka and Rao (1957) and Ghosh *et al.* (1958) in crosses involving N.P. 790.

Red grain colour conditioned by a single dominant factor has also been reported by a number of workers including Clark (1924), Hayes and Robertson (1924), Waterhouse (1930) Kadam (1936), Sears (1944), Heyne and Livers (1953), Lakhani (1956), Khan (1956).

SUMMARY

Results of the studies on the mode of inheritance of field reaction to black rust and certain other characters in some intervarietal crosses of *T. aestivum* are reported and discussed.

Inheritance of field reaction to black rust, studied in the crosses Pb.C. 518(S) × N.P. 790(R) and Pb.C. 273(S) ×N.P. 790(R) was found to be controlled by three factor pairs giving a 61S:3R ratio.

Grass clump habit was found to be conditioned by three recessive genes in the crosses E. 871 ×N.P. 718, E. 871 ×Pb.C. 281, E. 957 ×Pb.C. 518, Pb.C. 273 ×N.P. 790 and Pb.C. 518 ×N.P. 790.

Necrotic leaf spots were found to be inherited on a simple monofactorial basis in the cross Pb.C. 273 (nec.) ×N.P. 790 (normal).

Inheritance of anthocyanin pigmentation of the rachis was found dependent upon interaction between a dominant factor for pigmentation and an inhibitor in the crosses Pb.C. 273 (Gr) ×N.P. 790(P) and Pb.C. 518 (Gr) ×N.P. 790.

In both the crosses, viz., Pb.C. 518(A) ×N.P. 790(AL) and E. 871(A) ×N.P. 165(AL), awning was found to be controlled by two factors, with partial dominance of awnlessness over awnedness.

Glume beak shape in the crosses Pb.C. 518 (acuminate) ×N.P. 790 (obt.) and E. 871 (ocum.) ×N.P. 165 (obt.) was inherited on a bifactorial basis, with partial dominance of obtuse beak shape.

Glume pubescence was found to be conditioned by a single gene difference, with dominance of pubescent condition in the crosses E. 871 (Gl) ×Pb.C. 281(P), E. 957(Gl) ×Pb.C. 518(P), Pb.C. 518(P) ×N.P. 790(Gl) and Pb.C. 273(P) ×N.P. 790(Gl).

Brown glume colour was found monogenically dominant over white glume colour in the cross Pb.C. 518(W) ×N.P. 790(Br) and Pb.C. 273(W) ×N.P. 790(Br).

Square glume shoulder was observed to be incompletely dominant over wanting shoulder and monogenically controlled in the crosses Pb.C. 273(W) ×N.P. 790(S) and Pb.C. 518(W) ×N.P. 790(S).

Red grain colour was found dominant and controlled by one factor in the cross Pb.C. 518(A) ×N.P. 790(R) and by three factors in the cross E. 957(R) ×Pb.C. 518(A).

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Jute in India by B. C. KUNDU, K. C. BASAK, and P. B. SARKAR. The Indian Central Jute Committee, Calcutta, 1959. pp. 395, Figs. 74. Price Rs. 30·00.

Jute is next to cotton in its importance as a textile fibre and our most important crop for earning foreign exchange. Together with Pakistan, India grows about 98 per cent of the world requirements of jute. A considerable amount of research has been done on botany, cultivation and technology of jute in India for a long time and it is on the cumulative results of the vast data so far obtained that this monograph is based. Besides reviewing the progress made in the various fields of jute, the monograph gives an assessment of the present position in jute research and future possibilities of improvement in its research and trade.

The Monograph *Jute in India* is divided into three sections.

Section I deals with agriculture and is compiled by Dr. B. C. Kundu, a jute researcher of long standing and till recently the Director of the Jute Agricultural Research Institute, Barrackpur.

It is stated that the most important textile fibre next to cotton is jute. It is extensively used in the manufacture of different types of packing material and has a number of other industrial uses. Raw jute and its finished products form the main source of foreign exchange in this country.

The jute fibre is obtained from the bark of a cultivated plant called *Corchorus*. According to an earliest record, jute is said to have been cultivated in Bengal, Iraq and South China and it formed an important item of trade during the 16th century in Bengal. Jute is supposed to have been derived from the Sanskrit word *juta* and the word jute was first used by Roxburgh in about 1895; jute was first exported to Europe in 1828.

Corchorus includes about 40 species and is mainly a tropical genus. Eight species grow in India; of these, only two are commercially important. Dr. Kundu recently concluded that *C. olitorius* has a primary origin in Africa and secondary centre in India or Indo-Burma region; and that *C. capsularis* may have originated from the Indo-Burma region. The two cultivated species differ in a number of botanical features.

Since, in jute, a breeding technique is to be rigidly adhered to a definite jute-breeding technique was initiated during 1945 at the Jute Agricultural Research Laboratory, Dacca, and its substations. This technique takes into consideration selection, testing of breeding materials, records of germination, pigmentation, vigour study, flowering, plant height, thickness of stem, selfing and crossing. Research on improved strains of jute was initiated in 1900 and a number of strains have since been standardized in both *capsularis* and *olitorius*. D 154 and Chinsurah Green remained standard strains for many years. D 154, JRC 412, JRC 919, JRC 212 and JRC 321 are the important *capsularis* strains, JRO 620, JRO 632, and JRO 753 and those of *olitorius*.

An analysis of *capsularis* varietal trials showed that JRC 212 and JRC 919 gave the best yield; from among *olitorius*, JRO 753 and JRO 632 gave similar results. Multiple crossing at the JARI and irradiation with x-ray have also been attempted.

Inheritance of such characters as anthocyanin pigmentation, pod shape, its surface and size; cluster habit, branching habit, short branching habit, stipule character, bitter taste, undulate leaf, colour of anther and corolla, flower size, seed coat colour, etc., have been investigated into. Anther pigmentation patterns are given for *capsularis* in a tabular form.

Chromosome numbers of seven species are given. The haploid number is seven, polyploidy, hypo- and hyperploidy have been also observed. Meiosis, pollen studies of some species and types, interspecific cross-in-compatibility between *capsularis* and *olitorius* and factors involved in it, interspecific crosses at diploid and tetraploid levels in cultivated species have also been undertaken.

Anatomy of the stem, its distinguishing characters in *capsularis* and *olitorius*, structure of ultimate fibre cells, development of fibres and their bearing of plant height and base diameter; origin and development of fibres, effect of environment, soil, etc., on their formation, effect of date of sowing of these, their structure and quality, including seedling anatomy, and anatomy of retted jute are given.

Physiology of the seed has been discussed with reference to natural viability percentage, germination of seeds harvested at different stages and harvesting jute for the dual purpose of seed and fibre. Root systems are described by fresh weight and the proportion of shoot growth to root growth is found to be 18 to 20 per cent.

Development of the jute plant has been studied under vernalization and photoperiodic treatments.

Characters such as water relation in jute, nature of flowering and seed-formation and physiology of growth, growth of fibre-variation in its growth and the resultant effect of the nature of the fibre produced, have been taken into consideration for evolving criteria for selection of jute.

Soils of the important jute-growing states of India have been described and their geographical distribution figuratively illustrated. The climatic conditions favourable for optimum growth of jute are enumerated.

Different practices evolved in the cultivation of jute in the jute-growing districts have been discussed at length from the earliest to the present times. Special emphasis has been laid on scientific methods of extraction of the fibre. Self-explanatory illustrations add great value to this chapter.

The various characters used by the mills to assess the quality of jute have been described; characters of the defective fibre, with suggestions for its improvement, are given.

The seed-producing capacity of the crop and various factors affecting better production of seeds are discussed. A comparison of yields from crops raised from old and fresh seeds is given. The fungal and physiological diseases of the jute crop are discussed and varietal resistance of the important varieties of *capsularis* and *olitorius* given in a tabular form. Control measures of the major as well as minor diseases of jute are included, stem rot receiving special attention.

The biology and the control of insect pests of jute have been discussed with respect to the most important strains of *capsularis*, and *olitorius*, and the utility of the various insecticides in the control of these pests is given.

Section II includes elaborate and comprehensive information on economic and marketing problems of jute and jute manufacture. It is compiled by Shri K. C. Basak, Director, Economic Research Institute. It is reported that economic and marketing problems of jute are varied and complex as they extend from the field to the factory and thence to the world market. Shri Basak has particularly dealt with the economics of jute-growing, and the marketing and transport of jute and jute goods.

Economics of jute-growing gives a detailed account of cost of production of jute; profit, loss and income and structure of operational costs in jute cultivation; problems of agricultural labour; income from jute to the farmers, expenditure on its cultivation, the effect of cash resources of farmers on jute cultivation; and comparative economics of jute and jute production. The chapter is sprinkled with statistical data, tables and idiograms depicting the various aspects discussed.

Production economics of jute cultivation under the improved and traditional methods and the effect of manures and fertilizers on jute yield are also prominently featured.

Crop-cutting experiments on jute are said to be operating since 1952, and their statistical limitations are discussed; the results obtained have been found to be quite consistent. A comprehensive account on the marketing and transport of jute in India and the marketing of jute products in India and the world markets form a very interesting study of this Section. The bulk production of jute with reference to India and Pakistan is given. Statistics of the mofussil price of jute and their bearing on marketing of jute in India, and later their intrinsic influence on the world market, are appropriately recorded. The role of transport in the jute trade industry and the difficulties encountered by it in the post-partition India is geographically illustrated with reference to important jute-growing tracts of India. A special chapter is devoted to the allied fibres of jute, such as sannhemp, mesta etc., and their uses.

The use of alternative and competitive potential of substitute for jute fibre in foreign countries as packing material is shown to pose a great threat to the jute industry in India, and disadvantages of gunny for packing cement etc., are discussed. The production potential of substitutes for jute in the U.S.A., Canada, U.K., Australia, Africa, etc., and the plants used to provide these substitutes are given. The production (in tons) of these various substitutes in foreign countries is given in a tabular form. World consumption of jute is geographically illustrated. The U.S.A. appears to be the most important market for jute goods. The post-war effects do not seem to have affected the Indian jute industry.

An economic analysis of some aspects of demand and supply of jute and the jute manufacture in the American market are discussed. The concluding chapters in this section are devoted to problems of jute growers, raw jute prices, consumption of jute at the village level, future markets for jute and establishment of raw jute markets, and a running reference to Nepal jute and its infiltration into India.

Section III is devoted to jute technology. It is written by Dr. Sarkar who, as Director of the Technology Research Laboratory, has gained considerable experience in this field of research. A review of physical characters of the jute fibre gives information on the structure and nature of this fibre, characters of meshes, their water-holding capacity and swelling strength. The x-ray study of jute fibres has shown that it is a

consistent crystalline area with a high degree of order in its molecular arrangement. The chemistry of the jute fibre includes information on its chemical composition, the presence of various antibiotics and other chemical peculiarities such as presence of mineral matters, lignin, acids, etc.; bleaching of jute, its finishing and various methods of special processes, including the history and methods of processing, spinning and weaving, are discussed. The information on the latter is illustrated. The chemical composition of jute-substitutes and a comparison of qualities of the white and tosa jutes are given. Horticultural, agricultural, domestic and industrial uses of jute are also given. The concluding chapter is devoted to yarn-characters and grading of jute.

Sections I and II have a comprehensive bibliography at their respective ends and Section III has a detailed bibliography appended to each chapter.

The book is profusely illustrated and each photograph or a figure shows the great acumen of the artist concerned. Each illustration provides an audio-visual aid to the understanding of the accompanying chapter.

The production of the Monograph is good. It is bound to be highly useful to those interested in research on jute, its economics and marketing.

—*P. Kachroo*

The Insect pests of Cotton in Tropical Africa by E. O. Pearson, *assisted by* R. C. Maxwell Darling. Published jointly by The Empire Cotton Growing Corporation and the Commonwealth Institute of Entomology, London, 1958; Pp. x+355; price 40 sh.

The book is divided into four major sections, in addition to a foreword by Professor J. W. Munro, an introduction, an appendix on 'the use of insecticides on cotton in Africa' by Mr. R. C. Maxwell Darling, formerly Chief of the Research Division, Ministry of Agriculture, Sudan, 686 references to scientific literature and a 14½-page index. Eight coloured plates and 16 text figures complete the book. The first section deals with the botany of the cotton plant, 'characteristics and origin of the true cottons' and various aspects of cotton cultivation in Africa. The second section is devoted to some general considerations in relation to the systematic and geographical distribution of cotton insects, origins of cotton pests, effects of pest attack on yield, etc. The third section gives a field key for the recognition of the 'principal disorders' caused in the cotton plant not only by insects but also by mites, fungi, bacteria and viruses. The fourth section contains accounts of principal insect and mite pests of cotton, together with critical discussions on their taxonomy, economic status and control.

The author quotes a previous publication listing no less than 1,326 species of insects as having been collected from the cotton plant, though he rightly points out that the great majority of them are of no economic importance and many have been just casual visitors without even feeding on the plant. However, over 30 pest species attack the crop in different parts of the world of which at least six are responsible for serious losses in India. In a brief reference to locusts as pests of cotton, it is stated that 'the regular breeding grounds of the Desert Locust lie, for the most part, outside of

Africa, in the Arabian Peninsula.........' It is not clear what exactly is meant by 'regular breeding grounds'. There are large areas in Africa wherein the desert locust lives and breeds endemically and wherein gregarisation may take place and from which swarms may arise. There are also areas wherein summer-monsoon or winter-spring breeding occurs. Moreover, the Arabian Peninsula is not the only area wherein the desert locust breeds 'regularly'. Indeed, in Africa itself there are areas where the whole life-cycle of the desert locust may be sustained indefinitely without any swarm incursions from outside.

While there may be general agreement with much that has been said in the Appendix by Mr. Maxwell Darling, one cannot help feeling that the dangers and the difficulties of applying insecticides to control pests have been rather unduly highlighted. Insecticides no doubt destroy not only pests but also their parasites and predators, but insecticides are applied only when the beneficial insects have not proved effective. If the use of an insecticide leads to the appearance of a pest other than the one against which it was applied, choices have to be made about appropriate insecticides and timings of application or about not applying the insecticides at all. The repeated use of insecticides may create resistances in insects, but it is not an alarming situation if, after about 13 years of insecticidal uses, only '23 out of 5,000 species of economically important insects have formed resistant strains'. No one would recommend an insecticide to control a pest if its use did not result in increased yield sufficient to cover the cost of application and to leave a profitable margin of gain. While this may have to be established by large-scale field trials, it is not clear why 'the individual farmer has to decide whether the new practice pays him or not', when he has a right to expect that the appropriate organisation of his government would explain or demonstrate to his satisfaction the utility and the economics of a recommended measure.

An examination of the observations made and the results of experiments conducted in various parts of Africa over several years had led Mr. Maxwell Darling to doubt whether insecticidal treatments of the cotton crop increase yields sufficiently to make the treatments remunerative. Assuming that the answer is in the positive, he considers and rightly that while the 'big farmer can afford to buy his own machinery or employ a contractor', the peasant cannot do so except co-operatively, and co-operation is not always easy to achieve. A somewhat similar condition prevails in India, but remedies are being sought not exactly on the lines suggested by Mr. Maxwell Darling. Efforts are being made to produce cheap and simple types of spraying and dusting machines which the peasant may own and operate and to develop a network of Extension services to tell him with what, how and when to spray or dust. Co-operative farming is being encouraged and facilities of financial credit and subsidy are being provided, even though it is agreed in principle that 'it is not a sound policy' for government 'to be responsible for direct control measures against crop pests, other than those, like locusts, against which purely local measures are ineffective'. Anyway, Mr. Maxwell Darling's view that 'the yield of peasant-grown cotton crops in Africa could often be improved as much by timely sowing and weeding, or even, in some cases, by ensuring that the whole crop is harvested, as by the farmer undertaking the unfamiliar and exacting operation of applying insecticides' may have some limited

application somewhere sometimes, but by and large it can only be regarded as a counsel of despair. It advises small cotton growers to be content with whatever they can get by timely sowing, etc., and enduring pests since they cannot control them. It misses the important fact that even the best cultivated of crops may be ruined by pest attacks, and such attacks even in normal years may cause appreciable but avoidable reductions in yield.

Although the book deals with the pests of cotton in Africa, it contains a wealth of consolidated and critically assessed information of considerable value and interest to all those concerned with the cultivation of this crop in any part of the world.

—*K. B. Lal*

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